GUIDELINE DG04

Wind Turbine Design

Gearbox Design Analysis

Rev	Date	Author	Signature	Date	Approval	Signature	Notes

Rev.	Description
000111	Draft

NOTICE

CONTENTS

1 Introduction

This document is one of a set of Design Guidelines (DG) developed by the National Renewable Energy Laboratory (NREL) to assist manufacturers and designers with the task of developing and presenting a comprehensive wind turbine design. The guidelines provide useful tips for developing, analyzing and presenting a wind turbine design suitable to submit for Certification. They are NOT a set of requirements or in anyway intended to replace the standards chosen by the manufacturer or certification body. They are intended to be a set of suggestions to help the designer in completing their work.

Quality procedures are very important in gearbox design/specification and production. In this DG a suggested quality system is presented. It is by no means the only quality system that a manufacturer can establish. But parts of it or all of it could be used if the manufacturer decides that it is useful and efficient for their situation. Regardless of what system is used the standards call for a quality system.

The original draft of this guideline was performed by Geartech Inc. under contract to NREL. They were drafted as a comprehensive set of quality procedures and checklists to guide designers, procurement officials, design auditors, manufacturing engineers or anyone who plays a role in the development of gearboxes for wind turbines. Each of the NREL sponsored guidelines are then reviewed by industry experts to assure that they represent reasonable practice. They are revised periodically to assure they represent current practice.

The advice provided in this and other DG is not intended to represent a comprehensive plan for wind turbine design, but instead to complement and suggest alternatives to current design practices. Following any or all of the suggestions set forth in this or any DG will not inherently improve a design or guarantee its Certification, nor does it relieve its designers, engineers or manufacturers of any liability.

2 Scope

This Design Guideline presents suggestions for procurement, specification, design, quality assessment for gearboxes intended for use in wind turbines. It is one of a suite of Design Guidelines intended to assist with the application of the International Standards listed in section 4.

3 Document Organization

This document is organized differently than other NREL DGs in that it presents a suggested quality system for wind turbine gearboxes rather than textbook style technical design guidelines. There are sufficient gearing standards and text books available for such purposes. This DG presents quality procedures for each stage of the gearbox development process and checklists to help remind and record the successful completion of each of the stages. These procedures and checklists can form a common set of terminology for all the different people and organizations that must collaborate to complete a successful gearbox development.

4 Relevant Recognized Standards and Guidelines

The following is a list of standards, guidelines and other documents both referenced in this text, and considered useful corollary material for the reader. At the time of publication, the editions indicated were valid. All listed documents are subject to revision, and the reader is encouraged both to apply the most recent edition and record the edition of any documents applied in the design process. In this guideline there are additional standards referenced. They

are not listed here since their significance is better understood within the context of the discussion being presented in that text.

4.1 National Standards

AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

4.2 International Standards

IEC 61400-22: (Draft) Wind turbine generator systems. Wind turbine certification

IEC 61400-2: (1996-04), Wind turbine generator systems. Safety of small wind turbines

IEC 61400-1 Ed.2: (1999-02), Wind turbine generator systems. Safety Requirements

4.3 Design Guidelines

DG01: Loads Analysis

DG02: Strength Analysis

DG03: Yaw and Pitch Rolling Bearing Life

4.4 Significant Interpretations

Currently none are available.

5 Gearbox Quality Procedures

5.1 QP1000 Procurement Process

Company Name	QUALITY PROCEDURE	No. QP1000 Rev. A	SHEET 1 OF 2
Procurement Process		BY: *Author*	DATE *(date written)*
		CKD: Checker	DATE *(date checked)*

1. Scope

1.1 This procedure covers the steps involved in procuring gearboxes.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 *(Company Name)* Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Procurement process- The process of procuring gearboxes consisting of:

- Develop procurement specification
- Solicit bids
- Evaluate proposals/ select final bidders
- Meet for design reviews
- Select gear manufacturer
- Audit gearbox design
- Award Contract

Company Name	QUALITY PROCEDURE	No. QP1000	SHEET 2 OF 2
		Rev. A	
Procurement Process		BY: *Author*	DATE *(date written)*
		CKD: Checker	DATE *(date checked)*

Procurement Process *(continued)*

- Review and approve engineering drawings
- Review and approve quality assurance (QA) plan
- Review and approve manufacturing schedule
- Approve start of manufacturing
- Audit manufacturing
- Audit tests
- Audit gearbox startup

3.2 Bidder- Gear manufacturer who submits a proposal in response to bid solicitation.

3.3 Gear specialist- An engineer knowledgeable in design, manufacturing, and application of gearboxes.

3.4 Gear manufacturer- A manufacturer specializing in the manufacture of gearboxes.

3.5 Purchaser- Company purchasing a gearbox from a gear manufacturer.

3.6 Proposal- Gearbox design, QA Plan, manufacturing schedule, pricing, and warranty offered by a bidder.

3.7 Contract- Agreement between purchaser and gear manufacturer.

4. Significance and Use

4.1 Procurement process- AGMA/AWEA 921-A97, Annex D explains the procurement process including procurement specification, QA plan, quality control tests, quality documentation, and responsibilities of purchasers and gear manufacturers (see CK1000).

5. Procedure

5.1 Checklists- CK2000 through CK9000 shall be used for guidelines for all aspects of the procurement process from writing the procurement specification to auditing gearbox startup.

5.2 Quality procedures- QP2000 through QP9000 shall be used for quality procedures for all aspects of the procurement process from writing the procurement specification to auditing gearbox startup.

5.3 Management- The procurement process involves many steps that evolve over time (typically at least one year). Therefore, the purchaser must have resources adequate to ensure that each step of the procurement process is properly implemented and all requirements of the procurement specification are met. See CK1000 for overall guidelines covering the procurement process.

5.2 QP2000 Procurement Specification

Company Name	QUALITY PROCEDURE	No. QP2000	SHEET 1 OF 2
		Rev. A	
Procurement Specification		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

1. Scope

1.1 This procedure covers writing procurement specifications.

2.

1.1.1.1.1.1 Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 *(Company)* Specifications:

1.1.1.1.2	CK1000	QP1000	Procurement process
1.1.1.1.3	CK2000	QP2000	Procurement specification

3. Terminology

3.1 Procurement specification- Specification designed and maintained by the purchaser that defines the application, load spectrum, and minimum requirements for design, manufacturing, quality assurance, testing, and gearbox performance (see CK2000).

4. Significance and Use

4.1 Procurement specification- AGMA/AWEA 921-A97, Clause 4 is a guide for developing a procurement specification for wind turbine gearboxes.

4.2 Features- The procurement specification defines requirements and methodology for obtaining reliable gearboxes for wind turbine service. A good procurement specification does the following:

- Defines purchaser's requirements
- Provides common language to aid communication between purchaser, bidders, and gear manufacturer
- Provides methods for comparing competing proposals
- Specifies quality assurance inspections, tests, and acceptance criteria

5. Procedure

5.1 Responsibilities- The procurement Specification shall be designed and maintained by the purchaser. The gear manufacturer shall design and maintain a quality assurance (QA) plan that is adequate to achieve quality goals defined by the procurement specification.

Company Name	QUALITY PROCEDURE	No. QP2000	SHEET 2 OF 2
		Rev. A	
Procurement Specification		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

5.2 Management- The purchaser shall commit resources adequate to properly implement, distribute, and maintain the procurement specification.

5.3 Procurement specification- AGMA/AWEA 921-A97 shall be used as a guide for developing a procurement specification.

5.4 Checklists- CK2000 shall be used for guidelines for content of a procurement specification.

5.5 Procurement process- CK1000 and QP1000 shall be used for guidelines covering the procurement process.

5.6 Technical requirements- The procurement specification shall be audited by a gear specialist to ensure technical requirement are adequately specified.

5.3 QP3000 Bid solicitation and evaluation

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 1 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked*

1. Scope

1.1 This procedure covers soliciting and evaluating bids.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule

3. Terminology

3.1 Bid solicitation- Purchaser sends request for proposal to qualified gear manufacturers with the procurement specification and other information necessary for bidders to evaluate the project and prepare proposals.

3.2 Bid evaluation- Purchaser evaluates bids for compliance to the procurement specification, bidder experience and capability, pricing, delivery, and warranty.

3.3 Qualified gear manufacturer- Manufacturer with proven experience and capability necessary to produce gearboxes that conform to the procurement specification.

4. Significance and Use

4.1 Bid solicitation and evaluation- AGMA/AWEA 921-A97, Annex D explains the procurement process including bid solicitation and evaluation.

5. Procedure

5.1 Bid solicitation- Only qualified gear manufacturers shall be asked to bid. See CK1000 through CK7000 and QP1000 through QP7000 for guidelines for bid solicitation.

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 2 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked*

5.1.1 Bid package- Purchaser documents shall include request for proposal, bidding instructions, and the procurement specification.

5.1.2 Bidding instructions- Sheet 2 through sheet 9 are sample bidding instructions.

5.1.3 Procurement specification- See CK2000 and QP2000 for procurement specification guidelines.

5.2 Bid evaluation- See CK1000 through CK7000 and QP1000 through QP7000 for guidelines for bid evaluation.

Company Name	QUALITY PROCE-DURE	No. QP3000	SHEET 3 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked*

BIDDING INSTRUCTIONS

To be considered, proposals must show full understanding and compliance with Procurement Specification No. <number>. Additionally, the following requirements must be met:

- Proposals shall be received at Purchaser no later than close of business on the day specified in the Request For Proposal that invokes Procurement Specification No. <number>.
- Proposals shall be Lump Sum, First, and Firm.
- Proposals shall include the following:
- Completed proposal including pricing, delivery, and warranty
- List of exceptions to procurement specification
- Preliminary Quality Assurance Plan
- Completed questionnaire
- Layout (assembly) drawing of gearbox
- Outline dimension drawing of gearbox
- Metallurgical and geometric data for all gears
- Bearing data
- Load/life calculations for gears and bearings
- Lubrication data
- Proposals shall be sent to :

<addressee>
<address>
<address>
<address>

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 4 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked*

BIDDING INSTRUCTIONS (continued)

- Proposal forms : To ensure uniform proposals, bidders are required to submit the attached forms. Bidders should include their experience in design and manufacture of similar gearboxes. Technical capability, experience, price, delivery, and warranty shall be considered in bid evaluations.

- Preliminary Quality Assurance Plan : Bidders may complete and submit the attached SAMPLE QUALITY ASSURANCE PLAN for the preliminary QA Plan. However, the final QA Plan shall be the bidder's responsibility.

- Questionnaire : To avoid misunderstanding, bidders are required to submit the attached questionnaire. All questions must be answered completely. Incomplete answers may cause rejection of bid.

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 5 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

PROPOSAL

ITEM	NET PRICE EACH
Gearbox	
Tooling, fixtures, and cutters	
Engineering and design	
Subcontract effort	
First article tests	
Shipping	
Total cost	

DELIVERY SCHEDULE

ITEM	CALENDER DAYS AFTER RELEASE OF PURCHASE ORDER
Final QA plan	
Manufacturing schedule	
Engineering drawings	
Gear Forgings	
Gear heat treat	
Gear grinding	
Gearbox assembly	
Gearbox test	
Shipment	

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 6 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BID CERTIFICATION

I certify that this proposal, unless otherwise noted in Exceptions to Specification, meets all requirements of Procurement Specification No. <number>.

Engineering Manager :_____Date :_____.

Quality Assurance Manager :_____Date :_____.

Purchasing Agent :_____Date :_____.

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 7 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

WARRANTY

(Attach additional sheets if necessary)

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 8 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

EXCEPTIONS TO PROCUREMENT SPECIFICATION No. <number>

(*List specific clause and propose exact wording. If there are no exceptions, please state so. Attach additional sheets if necessary*)

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 9 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

SAMPLE QUALITY ASSURANCE PLAN

Page 1 of 4

LEGEND

H = Hold Point – Operation or procedure must be witnessed by purchaser's representative before moving component to next operation.

W = Witness Point – Operation or procedure may be witnessed by purchaser's representative if purchaser's representative is present during manufacture.

D = Document Required – Quality assurance must provide certified copy of inspection or test report to purchaser's representative.

Procurement Specification No. <number> Rev. <letter>

Activity	H	W	D	Procurement Specification Clause No.	Bidder Spec. No.	Bidder Clause No.	Bidder Form No.
Gear raw material	X		X				
Process	X		X				
Form	X		X				
Chemistry	X		X				
Grain size	X		X				

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 10 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

SAMPLE QUALITY ASSURANCE PLAN

Page 2 of 4

Activity	H	W	D	Procurement Specification Clause No.	Bidder Spec. No.	Bidder Clause No.	Bidder Form No.
Hardenability	X		X				
Cleanliness	X		X				
UT inspect forgings	X		X				
Inspection of gear teeth	X		X				
Basic geometry		X	X				
Accuracy	X		X				
Root fillets		X	X				
Grinding stock removal		X	X				
Surface roughness	X		X				
Magnetic particle	X		X				
Surface temper	X		X				
Surface hardness	X		X				
Inspection frequency	X		X				
Inspection of coupons	X		X				
General	X		X				

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 11 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

SAMPLE QUALITY ASSURANCE PLAN

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Activity	H	W	D	Procurement Specification Clause No.	Bidder Spec. No.	Bidder Clause No.	Bidder Form No.
Case hardness	X		X				
Case depth	X		X				
Core hardness	X		X				
Case microstructure	X		X				
Carbides	X		X				
Decarburization	X		X				
Carbon content	X		X				
Microcracks	X		X				
Sec. transform. prod.	X		X				
Intergranular oxidation	X		X				
Retained austenite	X		X				
Core microstructure	X		X				
Post carburize cold treat		X	X				
Housing accuracy		X	X				
Shaft material		X	X				

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 12 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

SAMPLE QUALITY ASSURANCE PLAN

Page 4 of 4

Activity	H	W	D	Procurement Specification Clause No.	Bidder Spec. No.	Bidder Clause No.	Bidder Form No.
Shaft hardness		X	X				
Shaft accuracy		X	X				
Shaft magnetic particle		X	X				
First article tests	X		X				
Contact patterns	X		X				
No load tests	X		X				
Lubrication	X		X				
Dykem	X		X				
Sound level	X		X				
Vibration level	X		X				
Oil leaks	X		X				
Oil sump temperature	X		X				
Corrective action	X		X				
Documentation	X		X				
Preparation for shipment	X		X				

Bidder Company Name :

NOTES:

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 13 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

QUESTIONNAIRE

QUESTION	RESPONSE
1- Has bidder read and understood the procurement specification?	
2- Is bidder prepared to perform work in conformance with the procurement specification?	
3- Is bidder prepared to attend a design review meeting and present the following:	
• Completed proposal including pricing, delivery, and warranty	
• List of exceptions to procurement specification	
• Preliminary Quality Assurance Plan	
• Completed questionnaire	
• Layout (assembly) drawing of gearbox	
• Outline dimension drawing of gearbox	
• Metallurgical and geometric data for all gears	
• Bearing data	
• Load/life calculations for gears and bearings	
• Lubrication data	

Bidder Company Name :

Company Name	QUALITY PROCEDURE	No. QP3000	SHEET 14 OF 14
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

BIDDING INSTRUCTIONS

QUESTIONNAIRE

QUESTION	RESPONSE
4- Does bidder understand that outline, assy, and detailed gear drawings shall be supplied to purchaser after purchase order?	
5- Does bidder understand that manufacturing is not to proceed without written approval from purchaser?	
6- Does bidder understand the specification requirements for geometric quality?	
7- Does bidder understand the specification requirements for metallurgical quality?	
8- Does bidder understand the specification requirements for heat treatment coupons?	
9- Does bidder understand specification requirements for magnetic particle and surface temper inspection?	
10- Does bidder understand specification requirements for First Article Tests?	
11- Is bidder prepared to assign a technical person to be responsible for all technical interface with purchaser?	
12- Does bidder understand purchaser's representative shall witness all tests and inspections, as agreed to in QA Plan?	
13- Are all forgings 100% UT inspected, both radially and axially, at forge shop and bidders shop?	
14- Does bidder have all necessary tooling, fixtures, and cutters required to produce pinions and gears?	
15- If response to question 14 is no, provide estimated time and cost to purchaser.	
16- Will pinion and gear teeth be rough cut by hobbing or shaping?	
17- On what specific machines will pinion and gear teeth be rough cut?	
18- Will pinion and gear teeth be finished by hard cutting or grinding?	
19- On what specific machines will pinion and gear teeth be finished?	
20- On what specific machines will pinion and gear teeth be inspected?	

Bidder Company Name :

5.4 QP4000 Gearbox design audit

Company Name	QUALITY PROCEDURE	No. QP4000	SHEET 1 OF 3
		Rev. A	
Gearbox Design Audit		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

1. Scope

1.1 This procedure covers the steps involved in auditing gearbox design.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ANSI/AGMA 2101-C95 Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth.

2.3 ANSI/AGMA 6001-D97 Design and Selection of Components for Enclosed Gear Drives.

2.4 ANSI/AGMA 6010-E88 Standard for Spur, Helical, Herringbone, and Bevel Enclosed Gears.

2.5 ANSI/AGMA 6023-A88 Design Manual for Enclosed Epicyclic Gear Drives.

2.6 ANSI/AFBMA Std 11-1990 Load Ratings and Fatigue Life for Roller Bearings.

2.7 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK4100	QP4100	Gear design Audit
CK4200	QP4200	Bearing design audit
CK4300	QP4300	Shaft design audit
CK4400	QP4400	Housing design audit
CK4500	QP4500	Lubrication system audit

3. Terminology

3.1 Gearbox design audit- The process of determining if the proposed gearbox and all of its components meet the requirements of the Procurement Specification.

4. Significance and Use

Company Name	QUALITY PROCEDURE	No. QP4000	SHEET 2 OF 3
		Rev. A	
Gearbox Design Audit		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

4.1 Significance and Use- A complete gearbox design audit including but not limited to gear detail drawings, assembly drawings and layout drawings is necessary to ensure the design meets the requirements of the procurement specification and has adequate capacity for the application.

5. Procedure

5.1. Proposal data- The proposal shall include all data listed in CK4000.

5.2 Gear Calculations- Gear calculations shall be performed per Section 4.3.1, of AGMA/AWEA 921-A97, Gear Life Rating, and QP4100.

5.3 Gearbox thermal rating- Gearbox thermal rating shall be performed per Section 4.3.2, of AGMA/AWEA 921-A97, Gearbox Thermal Rating, and QP4100.

5.4 Bearing calculations- Bearing calculations shall be performed per Section 4.3.3, of AGMA/AWEA 921-A97, Bearing Life Calculations, and QP4200.

5.5 Shaft Calculations- Shaft Calculations shall be performed per Section 4.3.4, of AGMA/AWEA 921-A97, Shaft Life Ratings, and QP4300.

5.6 Housing calculations- Housing calculations shall be performed as per Section 4.3.5, of AGMA/AWEA 921-A97, Housing, and QP4400.

5.7 Lubrication system- The lubrication system shall be audited for conformance to Section 4.8 of AGMA/AWEA 921-A97, Lubrication System, and QP4500.

5.8 Maintainability- The gearbox and lubrication system shall be audited for conformance to Annex E of AGMA/AWEA 921-A97, Operation and Maintenance, and the procurement specification.

6. Interpretation of Results

6.1 Specification conformance- The results of the gearbox design audit shall be compared to the requirements of the procurement specification for the following categories:

- Design features
- Load capacity
- Lubrication system
- Maintainability

7. Acceptance Criteria

7.1 Design features- Gearbox design features shall meet the requirements of AGMA/AWEA 921-A97 and the Procurement Specification.

Company Name	QUALITY PRO-CEDURE	No. QP4000	SHEET 3 OF 3
		Rev. A	
Gearbox Design Audit		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

7.2 Load capacity- Gearbox components shall have load capacities meeting the requirements of the following Quality Procedures:

1.1.1.1.4 QP4100 Gear design audit
QP4200 Bearing design audit

QP4300 Shaft design audit

1.1.1.1.5 QP4400 Housing design audit

7.3 Lubrication System- The lubrication system shall meet the requirements of QP4500.

7.4 Maintainability- Gearbox maintainability shall meet the requirements of AGMA/AWEA 921-A97 and the Procurement Specification.

7.5 Gearbox design audit- The gearbox design shall meet the requirements of the Procurement Specification.

8. Report

8.1 The report shall include the following:

8.1.1 Summary of gear life ratings and thermal ratings,

8.1.4 Summary of housing calculations,

8.1.5 Summary of lubrication system audit,

8.1.6 Summary of maintainability audit, and

8.1.7 Recommendations for revisions to engineering specifications required for conformance to the procurement specification.

Company Name	QUALITY PROCEDURE	No. QP4100	SHEET 1 OF 6
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written*)
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers rating analysis methods for determining Hertzian and bending fatigue lives, and probability of scuffing per AGMA/AWEA 921-A97 and AGMA 2001-C95. It also includes guidelines for avoiding micropitting.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ANSI/AGMA 2000-A88 Gear Classification and Inspection Handbook.

2.3 ANSI/AGMA 2001-C95 Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth.

2.4 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK4100	QP4100	Gear design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit
CK8100	QP8100	Gear raw material
CK8200	QP8200	Gear tooth cutting
CK8300	QP8300	Heat treatment of carburized gears
CK8400	QP8400	Gear tooth grinding
CK8500	QP8500	Gear tooth inspection

Company Name	QUALITY PROCEDURE	No. QP4100	SHEET 2 OF 6
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

3. Terminology

3.1 Definitions- See referenced documents for definition of terms.

3.2 Load distribution factor- The ratio of maximum load intensity to mean load intensity. See ANSI/AGMA 2001-C95 for factors influencing load distribution.

3.3 Dynamic factor- The ratio of dynamic gear tooth load to static gear tooth load. See ANSI/AGMA 2001-C95 for factors influencing dynamic load.

3.4 Contact temperature- The sum of the gear tooth and flash temperatures. The maximum value along the line of action is compared to the scuffing temperature to assess risk of scuffing.

3.5 Gear tooth temperature- The equilibrium temperature of the surface of gear teeth before they enter the contact zone. Tooth temperature may be significantly higher than the temperature of oil supplied to the gear mesh.

3.6 Flash temperature- The instantaneous rise in gear tooth surface temperature at a given point along the line of action resulting from combined effects of gear tooth geometry, load, friction, velocity and material properties.

3.7 Scuffing temperature- The contact temperature at which scuffing is likely to occur with the chosen combination of lubricant and gear materials. The mean scuffing temperature is the temperature at which there is a 50% chance scuffing will occur.

3.8 Lubricant dynamic viscosity- The viscosity used in lubricant film thickness calculations is dynamic viscosity measured in units of centipoise (cP). ANSI/AGMA 2001-C95 Annex A gives values of dynamic viscosity versus gear tooth temperature.

3.9 Lubricant pressure-viscosity coefficient- Calculations of lubricant film thickness require the pressure-viscosity coefficient, which characterizes exponential increase in viscosity with pressure. ANSI/AGMA 2001-C95 Annex A gives values of pressure- viscosity coefficient versus gear tooth temperature.

3.10 Lubricant micropitting resistance- A standard test used to determine micropitting resistance in accordance with FVA-Information Sheet “Micropitting,” No. 54/7 (July 1993) Forschungsvereinigung Antriebstechnik e.V., Lyoner Strasse 18, D-60528 Frankfurt/Main.

3.11 Aspect ratio- The ratio of pinion face to pinion operating pitch diameter.

3.12 Transverse contact ratio- The ratio of the angle of action to angular pitch. It is a measure of the number of teeth in contact and smoothness of gear tooth meshing.

3.13 Axial contact ratio- The ratio of active face width to axial pitch. It is a measure of the number of teeth in contact and smoothness of gear tooth meshing.

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		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

3.14 S_{at} – The allowable bending stress number per ANSI/AGMA 2001-C95.

4. Significance and Use

4.1 Gear rating analysis- The gear design audit determines if gears have adequate load capacity to conform to requirements of AGMA/AWEA 921-A97 and the procurement specification. AGMA standards do not provide rating methods for micropitting lives, but this quality procedure suggests methods for minimizing probability of micropitting.

5. Procedure

5.1 Checklist and quality procedures- CK1000 through CK4000 and QP1000 through QP4000 shall be used as guidelines for required data for gear design audits. CK4100 shall be used as a guideline for gear design audits.

5.2 Specification conformance- Gear rating calculations shall be performed in accordance with AGMA/AWEA 921-A97 and the procurement specification.

5.3 Metallurgical quality- AGMA/AWEA 921-A97 requires metallurgical quality meeting requirements for grade 2 material in accordance with ANSI/AGMA 2001-C95, with exceptions on core hardness, cleanliness, surface temper, and hardenability. If the gear manufacturing audit shows all gears meet requirements of grade 2 material, design audit calculations may assume grade 2 metallurgical quality. See CK5000 through CK8500, and QP5000 through QP8500.

5.4 Geometric quality- AGMA/AWEA 921-A97 requires geometric quality meeting requirements for Q11 accuracy in accordance with ANSI/AGMA 2000-A88. If the gear manufacturing audit shows all gears meet requirements of Q11, design audit calculations may assume Q11. See CK8500 and QP8500.

5.5 Load distribution factor- The load distribution factor may be calculated using the empirical method of ANSI/AGMA 2001-C95. However, a value ≥ 1.25 shall be used.

5.6 Dynamic factor- The dynamic factor may be calculated using the empirical method of ANSI/AGMA 2001-C95. Transmission accuracy number (Qv) shall be based upon the quality of the gears. However, Qv shall not exceed Qv = 11 for rating purposes.

5.7 Hertzian fatigue

5.7.1 Macropitting life rating- Calculations shall be performed per Section 4.3.1 of AGMA/AWEA 921-A97, Gear life rating and CK4100.

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Gear Design Audit		BY: *Author*	DATE *(date written)*
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5.7.2 Micropitting resistance- Wind turbine gears require smooth surfaces to ensure adequate load capacity. This is especially important for micropitting resistance. Maximum surface roughness shall be as specified in Table 1.

Table 1 Maximum Gear Tooth Surface Roughness

Gear	Maximum Roughness Ra (μm)
HS pinion and gear	0.7
INT pinion and gear	0.7
LS pinion and gear	0.6
LS sun and planet	0.5

Lubricant viscosity shall conform to requirements of AGMA/AWEA 921-A97.

Lubricant micropitting resistance shall be ≥ 10 failure load stage in accordance with FVA project number 54 test.

Active flanks of gear teeth shall not be shot peened because shot peened flanks may produce micropitting on mating gear teeth.

For maximum micropitting resistance, pinions should be at least 2 HRC points harder than gears. This is especially important for sun pinions.

See AGMA/AWEA 921-A97, Annex G for further information about surface roughness and boundary lubrication.

5.8 Bending fatigue

5.8.1 Bending fatigue life rating- Calculations shall be performed per Section 4.3.1 of AGMA/AWEA 921-A97, Gear life rating and CK4100.

5.8.2 Idler and planet gears- Calculations shall use 70% of S_{at} for idler and planet gears.

5.9

1.1.1.1.6 Scuffing probability

5.9.1 Scuffing probability- Calculations shall be performed per Section 4.3.1 of AGMA/AWEA 921-A97, Gear life rating and CK4100.

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5.9.2 Scuffing temperature- If scuffing temperature is determined from FZG tests, one load stage lower than the failure load stage shall be used for scuffing analysis.

5.9.3 Load for scuffing analysis- Contact temperature shall be calculated using the maximum load in the load spectrum.

5.9.4 Surface roughness for scuffing analysis- Contact temperature shall be calculated using the as-manufactured surface roughness of gear teeth.

5.10 Wear probability

5.10.1 Wear probability- Calculations shall be performed per Annex A of ANSI/AGMA 2001-C95.

5.10.2 Lubricant properties- Dynamic viscosity and pressure-viscosity coefficient shall correspond to the gear tooth temperature. ISO viscosity grade and lubricant cleanliness shall conform to requirements of AGMA/AWEA 921-A97.

5.10.3 Load for wear analysis- Specific film thickness shall be calculated using the maximum load in the load spectrum.

5.10.4 Surface roughness for wear analysis- Specific film thickness shall be calculated using the run-in surface roughness of gear teeth.

6. Interpretations of results

6.1 Specification conformance- Results of the gear design audit shall be compared to requirements of AGMA/AWEA 921-A97 and the procurement specification for the following categories:

- Macropitting life
- Micropitting resistance
- Bending fatigue life
- Scuffing probability
- Wear probability
- Design features

7. Acceptance criteria

7.1 Macropitting life- The macropitting life of all gears shall be ≥ 175,000 hours.

7.2 Micropitting resistance- Gears shall conform to the requirements of clause 5.7.2.

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		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written*)
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7.3 Bending fatigue life – The bending fatigue life of all gears shall be ≥ 175,000 hours.

7.4 Scuffing risk- The scuffing risk for all gears shall be < 5%.

7.5 Wear risk- The wear risk for all gears shall be < 5%.

7.6 Design features- Gear design features shall meet the requirements of AGMA/AWEA 921-A97 and the procurement specification.

8. Report

8.1 Report- The report shall include the following:

8.1.1 Summary of macropitting life ratings,

8.1.2 Summary of micropitting resistance,

8.1.3 Summary of bending fatigue life ratings,

8.1.4 Summary of scuffing probabilities,

8.1.5 Summary of wear probabilities,

8.1.6 Summary of design features,

8.1.7 Recommendations for revisions to engineering specifications to ensure conformance to AGMA/AWEA 921-A97 and the procurement specification.

Company Name	QUALITY PROCEDURE	No. QP4200	SHEET 1 OF 5
		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers rating analysis methods for determining load ratings and fatigue life of roller bearings per AGMA/AWEA 921-A97 and ANSI/AFBMA Std. 11-1990.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ANSI/AFBMA Std. 11-1990, Load Ratings and Fatigue Life of Roller Bearings.

2.3 ISO/DIS 4406 (SAE J1165), Hydraulic Fluid Power-fluids-method for coding level of contamination by solid particles.

2.4 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK4200	QP4200	Bearing design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Definitions- See referenced documents for definition of terms.

3.2 L1 life- Adjusted life for 1% failure probability.

3.3 L10 life- Nominal life for 10% failure probability.

3.4 a_1- Life adjustment factor for failure probability.

3.5 a_{23}- Life adjustment factor for material, bearing type, lubrication, and cleanliness.

3.6 Lubricant cleanliness- ISO/DIS 4406 cleanliness code.

Company Name	QUALITY PROCEDURE	No. QP4200	SHEET 2 OF 5
		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

4. Significance and Use

4.1 Bearing rating analysis- The bearing design audit determines if bearings have adequate load capacity to conform to requirements of AGMA/AWEA 921-A97 and the procurement specification.

5. Procedure

5.1 Checklist and quality procedures- CK1000 through CK4000 and QP1000 through QP4000 shall be used as guidelines for required data for bearing design audits. CK4200 shall be used as a guideline for bearing design audits. See CK5000 through CK8000 and QP5000 through QP8000 for guidelines for quality assurance.

5.2 Specification conformance- Bearing rating calculations shall be performed in accordance with AGMA/AWEA 921-A97 and the procurement specification.

5.3 Bearing features- Features such as type, arrangement, and retainers shall be compared to requirements of AGMA/AWEA 921-A97.

5.4 Shaft/housing fits- The range of fits for shafts and housings shall be calculated from tolerances given on engineering drawings.

5.5 Internal clearance- Specified internal clearance shall be compared to bearing manufacturer recommendations considering the range of shaft and housing fits.

5.6 Boundary dimensions- Shaft and housing boundary dimensions on engineering drawings shall be compared to bearing manufacturer recommendations.

5.7 Bearing assembly- Gearbox assembly shall be reviewed considering risk of damage to bearing components. This is especially important for blind assembly or separable, cylindrical-roller bearings.

5.8 Thermal growth- Bearing type and arrangement shall be reviewed considering accommodations for thermal growth.

5.9 L10 life rating- Life adjustment factors for reliability, material, and environment shall be taken as unity (1.0).

5.10 L1 life rating

5.10.1 Failure probability- Life adjustment factor shall be $a_1 = 0.21$ (failure probability 1%).

5.10.2 Lubricant properties- ISO viscosity grade and lubricant cleanliness shall conform to requirement of AGMA/AWEA 921-A97.

5.10.3 Operating viscosity- Operating viscosity shall correspond to operating temperature of rolling elements and raceways. Operating temperature shall be $\geq 80°C$.

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5.10.4 Lubricant cleanliness- Life adjustment factor a_{23} shall be consistent with oil filtration and actual oil cleanliness.

5.11 Minimum load- Minimum operating load shall be considered to ensure it is adequate to prevent skidding between rolling elements and raceways.

5.12 Cylindrical-roller thrust capacity- The ratio of axial to radial load (F_a/F_r) shall be evaluated to determine if axial loads are within thrust capacity of cylindrical-roller bearings.

5.13 Planet gear rim thickness- Rim thickness shall be evaluated to ensure it is adequate to prevent slipping of planet bearing outer races within planet bores.

6. Interpretations of results

6.1 Specification conformance- Results of the bearing design audit shall be compared to requirements of AGMA/AWEA 921-A97 and the procurement specification for the following categories:

- Bearing features
- Shaft/housing fits
- Internal clearance
- Boundary dimensions
- Bearing assembly
- Thermal growth
- L10 life
- L1 life
- Minimum load
- C-R bearing thrust capacity
- Planet gear rim thickness

7. Acceptance criteria

7.1 Bearing features- Bearing features shall meet the requirements of AGMA/AWEA 921-A97 and the procurement specification.

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		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
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7.2 Shaft/housing fits- All fits shall be tight, or adequate means shall be provided to prevent spinning of inner and outer races.

7.3 Internal clearance- Internal clearance shall conform to bearing manufacturer recommendations.

7.4 Boundary dimensions- Boundary dimensions shall conform to bearing manufacturer recommendations.

7.5 Bearing assembly- Adequate tooling and procedures shall be provided to avoid damage to bearing components.

7.6 Thermal growth- All shafts shall have bearing types and arrangements capable of accommodating thermal growth.

7.7 L10 life- Minimum calculated life shall be as shown in Table 1.

Table 1 Minimum Calculated L10 Life

Bearing Position	Required Life (hr)
HS pinion	40,000
INT shaft	40,000
LS shaft	100,000
Planet	140,000

7.8 L1 life- All bearings shall have a calculated life of L1 ≥ 175,000 hours.

7.9 Minimum load- All bearings shall have a low risk of skidding under the minimum load in the load spectrum.

7.10 C-R thrust capacity- All C-R bearings shall have adequate thrust capacity for imposed axial loads.

7.11 Planet gear rim thickness- Planet gear rim thickness shall equal at least three gear tooth modules.

8. Report

8.1 Report- The report shall include the following:

8.1.1 Summary of bearing features,

8.1.2 Summary of shaft/housing fits,

8.1.3 Summary of internal clearances,

Company Name	QUALITY PROCEDURE	No. QP4200	SHEET 5 OF 5
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Bearing Design Audit		BY: *Author*	DATE *(date written)*
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8.1.4 Summary of boundary dimensions,

8.1.5 Summary of bearing assembly,

8.1.6 Summary of thermal growth,

8.1.7 Summary of L10 life,

8.1.8 Summary of L1 life,

8.1.9 Summary of minimum load,

8.1.10 Summary of C-R bearing thrust capacity,

8.1.11 Summary of planet gear rim thickness,

8.1.12 Recommendations for revisions to engineering specifications to ensure conformance to AGMA/AWEA 921-A97 and the procurement specification.

Company Name	QUALITY PROCEDURE	No. QP4300	SHEET 1 OF 4
		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers rating analysis methods for determining load ratings and fatigue life of shafts per AGMA/AWEA 921-A97 and ANSI/AGMA 6001-D97.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ANSI/AGMA 6001-D97 Design and Selection of Components for Enclosed Gear Drives.

2.3 GEARTECH Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK4000	QP4000	Gearbox design audit
CK4300	QP4300	Shaft design audit
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Definitions- See referenced documents for definition of terms.

3.2 L1 life- Adjusted life for 1% failure probability.

3.3 Reliability factor k_c- Factor accounting for statistical variation in fatigue strength. See ANSI/AGMA 6001-D97.

3.4 Fatigue safety factor F_{sf}- See ANSI/AGMA 6001-D97 for definition.

3.5 Peak load safety factor F_{sp}- See ANSI/AGMA 6001-D97 for definition.

3.6 Maximum fatigue load- The maximum load shown in the load spectrum.

3.7 Peak load- The momentary, maximum load agreed to by purchaser and gear manufacturer. The peak load may be due to emergency brake stop, generator short circuit, utility grid event, or other transient condition.

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		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
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4. Significance and Use

4.1 Shaft rating analysis- The shaft design audit determines if shafts have adequate load capacity to conform to requirements of AGMA/AWEA 921-A97 and the procurement specification.

5. Procedure

5.1 Checklist and quality procedures- CK1000 through CK4000 and QP1000 through QP4000 shall be used as guidelines for required data for shaft design audits. CK4300 shall be used as a guideline for shaft design audits. See CK5000 through CK8000 and QP5000 through QP8000 for guidelines for quality assurance.

5.2 Specification conformance- Shaft rating calculations shall be performed in accordance with AGMA/AWEA 921-A97 and the procurement specification.

5.3 Geometric quality- Tolerances for diameters, lengths, surface roughness, straightness, circularity, parallelism, and radial and axial runout shall be reviewed considering requirements for operating accuracy of gears and bearings.

5.4 Fillets- Geometry of fillets at junctions of diameters and shoulders shall be reviewed considering requirements for clearance with mating components such as gears and bearings, and requirements for minimizing stress concentration.

5.5 Keyways- Geometry of keyways shall be reviewed considering requirements for fit with keys and minimizing stress concentrations.

5.6 Metallurgical quality- AGMA/AWEA 921-A97 requires all shafts be made from alloy steels with sufficient hardenability to obtain microstructures with strength and fracture toughness meeting the requirements of the application. Engineering drawings and quality assurance plan shall be reviewed considering requirements for metallurgical quality including inspections and tests.

5.7 Fatigue analysis

5.7.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

5.7.2 Failure probability- Reliability factor shall be $k_c = 0.817$ (failure probability 1%).

5.7.3 Load for fatigue analysis- Fatigue safety factor, F_{sf}, shall be calculated using the maximum fatigue load.

5.8 Yield analysis

5.8.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

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Shaft Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

5.8.2 Load for yield analysis- Peak load safety factor, F_{sp}, shall be calculated using the peak load.

5.9 Shaft/gear fits

5.9.1 Rating method- Torque capacity of interference fits shall be calculated per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97 and CK4300.

5.9.2 Load for calculating torque capacity- Slip torque shall be calculated using the peak load.

5.9.3 Coefficient of friction- Coefficient of friction shall be $f \leq 0.15$.

5.9.4 Keys- No benefit from keys shall be considered when calculating torque capacity.

5.9.5 Shaft/gear fits- The range of fits for shafts and gears shall be calculated from tolerances given on engineering drawings.

5.10 Deflection analysis

5.10.1 Rating method- Calculations shall be performed per AGMA/AWEA 921-A97, ANSI/AGMA 6001-D97, and CK4300.

5.10.2 Load for deflection analysis- Deflection shall be calculated using the maximum fatigue load.

6. Interpretations of results

6.1 Specification conformance- Results of the shaft design audit shall be compared to requirements of AGMA/AWEA 921-A97 and the procurement specification for the following categories:

- Geometric quality
- Fillets
- Keyways

6.1 Specification conformance *(continued)*

- Metallurgical quality
- Fatigue safety factor
- Yield safety factor
- Shaft/gear slip torque
- Deflection

7. Acceptance criteria

7.1 Geometric quality- Geometric quality shall be consistent with requirements for operating accuracy of gears and bearings.

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		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
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7.2 Fillets- All fillets shall have adequate clearance with mating components and adequate radii to avoid undue stress concentration. Surface roughness shall be Ra ≤ 1.6 μm.

7.3 Keyways- All keys shall be fitted to shafts with an interference fit. Inside corners of keyways shall have adequate fillet radii. Edges of keyways shall be deburred or chamfered. Keyways shall not extend into bearing journals.

7.4 Metallurgical quality- metallurgical quality shall be consistent with requirements for strength and fracture toughness.

7.5 Fatigue safety factor- Fatigue safety factor shall be $F_{sf} \geq 1.1$.

7.6 Yield safety factor- Peak load safety factor shall be $F_{sp} \geq 1.1$.

7.7 Shaft/gear slip torque- All shaft/gear fits shall have adequate torque capacity to transmit the peak load without slipping.

7.8 Deflection- Maximum deflection shall be consistent with load distribution factors used in gear rating (see QP4200). Maximum slope at bearings shall be within bearing manufacturer recommendations.

8. Report

8.1 Report- The report shall include the following:

8.1.1 Summary of geometric quality,

8.1.2 Summary of fillets,

8.1.3 Summary of keyways,

8.1.4 Summary of metallurgical quality,

8.1.5 Summary of fatigue safety factor,

8.1.6 Summary of yield safety factor,

8.1.7 Summary of shaft/gear slip torque,

8.1.8 Summary of deflection,

8.1.9 Recommendations for revisions to engineering specifications to ensure conformance to AGMA/AWEA 921-A97 and the procurement specification.

5.5 QP5000 Quality assessment

Company Name	QUALITY PROCEDURE	No. QP5000	SHEET 1 OF 2
		Rev. A	
Quality Assessment		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

1. Scope

1.1 This procedure covers quality assessment of a gear manufacturing facility.

2. Referenced Documents

2.1 ISO 9001 Quality Systems- Model for Quality Assurance in Design/Development, Production, Installation, and Servicing.

2.2 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.3 GEARTECH Specifications:

CK2000	QP2000	Procurement specification
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

Terminology

3.1 ISO 9001 registration- Gear manufacturer holds a “Certificate of Registration” that certifies the gear manufacturer’s quality assurance system has been assessed and registered by a recognized registrar in accordance with the provisions of ISO 9001.

3.2 Procurement specification- Specification designed and maintained by the purchaser that defines the application, load spectrum, and minimum requirements for design, manufacturing, quality assurance, testing, and gearbox performance (see CK2000 and QP2000).

3.3 Quality assurance plan- Manufacturing specification designed and maintained by the gear manufacturer that defines criteria for monitoring and controlling the manufacturing process (see CK6000 and QP6000).

3.4 Manufacturing schedule- Manufacturing specification designed and maintained by the gear manufacturer that defines the manufacturing sequence and schedules quality assurance tests (see CK7000 and QP7000).

3.5 Quality audit- Systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve requirements of the procurement specification.

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		Rev. A	
Quality Assessment		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

3.6 Manufacturing audit- Systematic and independent examination to determine whether manufactured product conforms to the requirements of the procurement specification.

4. Significance and Use

4.1 Quality audit- A quality audit is an excellent oppurtunity for the purchaser and gear manufacturer to reach a common understanding of quality goals. Quality audits can provide assurance that the quality plan, manufacturing schedule, and manufacturing procedures are adequate for achieving quality goals.

4.2 Registrar quality audit- Frequency of quality audits by the registrar range from every six months to every three years. If the registrar identifies serious nonconformities, the manufacturer's certificate can be revoked.

4.3 Internal quality audit- As part of a good quality system, a gear manufacturer should conduct internal audits to evaluate their own quality performance.

4.4 Manufacturing audit- After the quality audit shows the quality plan, manufacturing schedule, and manufacturing procedures are adequate for achieving quality goals, the purchaser may award the contract. Once manufacturing commences, the purchaser should audit manufacturing, inspection, and testing for conformance to the requirements of the procurement specification (see CK8000 and QP8000).

5.6 QP6000 Quality assurance plan

Company Name	QUALITY PROCEDURE	No. QP6000	SHEET 1 OF 2
		Rev. A	
Quality Assurance Plan		BY*: Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

1. Scope

1.1 This procedure covers auditing and approving quality assurance (QA) plans.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 *Company* Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Quality assurance plan- See QP5000.

3.2 Hold point- Operation or procedure must be witnessed by purchaser's representative before moving component to next operation.

3.3 Witness point- Operation or procedure may be witnessed by purchaser's representative if purchaser's representative is present during manufacture.

3.4 Document required- Quality assurance must provide a certified copy of inspection or test report to purchaser's representative.

4. Significance and Use

4.1 QA Plan- AGMA/AWEA 921-A97, Annex D explains the procurement process including procurement specification, QA plan, quality control tests, quality documentation, and responsibilities of purchasers and gear manufacturers (see QP1000).

4.3 Manufacturing audit- The QA plan informs manufacturer and purchaser of inspections and tests requiring hold points, witness points, and documentation.

Company Name	QUALITY PROCEDURE	No. QP6000	SHEET 2 OF 2
		Rev. A	
Quality Assurance Plan		BY: *Author*	*DATE (date written)*
		CKD: *Checker*	*DATE (date checked)*

5. Procedure

5.1 Responsibilities- The QA plan shall be designed and maintained by the gear manufacturer. The purchaser shall audit the QA plan to ensure that it is adequate to achieve quality goals. The purchaser's representative shall be responsible for witnessing inspections and tests defined by hold and witness points (see QP8000).

5.2 Preliminary QA plan- During bid solicitation and evaluation, bidders may submit a preliminary QA plan in accordance with QP3000. However, the final QA plan shall be the responsibility of the gear manufacturer.

5.3 Final QA plan- During bid solicitation and evaluation, bidders shall propose a deadline for the final QA plan (see QP3000). The purchaser shall enforce the deadline.

5.4 QA plan audit- The purchaser and gear specialist shall audit the QA plan for conformance to the procurement specification. See CK6000 for required content of QA plan. See QP3000 for a sample QA plan.

5.5 QA plan approval- Manufacturing shall not begin until the purchaser approves the QA plan. See QP1000 for guidelines covering the procurement process.

6. Acceptance Criteria

6.1 Inspections and tests- The inspections and tests specified in the QA plan shall meet the requirements of the procurement specification.

7. Report

7.1 The purchaser shall write a report that includes recommendations for revisions to the QA plan required for conformance to the procurement specification.

5.7 QP7000 Manufacturing schedule

Company Name	QUALITY PROCEDURE	No. QP7000	SHEET 1 OF 2
		Rev. A	
Manufacturing Schedule		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

1. Scope

1.1 This procedure covers auditing and approving manufacturing schedules.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 *(Company)* Specifications:

CK1000	QP1000	Procurement process
CK2000	QP2000	Procurement specification
CK3000	QP3000	Bid solicitation and evaluation
CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

3. Terminology

3.1 Manufacturing schedule- See QP5000.

3.2 Gantt chart- A list of tasks with a bar chart and timescale showing start and finish dates.

4. Significance and Use

4.1 Purpose- The manufacturing schedule specifies start and finish dates for significant steps of the manufacturing process including hold and witness points (see QP6000).

4.2 Manufacturing audit- The manufacturing schedule informs manufacturer and purchaser of the sequence of manufacturing and schedules quality assurance inspections and tests.

5. Procedure

5.1 Responsibilities- The manufacturing schedule shall be designed and maintained by the gear manufacturer. The gear manufacturer shall assign a contact person with adequate time and resources to provide timely progress reports. The purchaser shall audit the manufacturing schedule to ensure that it is adequate to achieve quality goals. The purchaser's representative shall be responsible for witnessing inspections and tests defined by hold and witness points (see QP8000).

Company Name	QUALITY PROCEDURE	No. QP7000	SHEET 2 OF 2
		Rev. A	
Manufacturing Schedule		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

5.2 Preliminary manufacturing schedule- During bid solicitation and evaluation, bidders may submit a preliminary manufacturing schedule in accordance with QP3000. However, the final manufacturing schedule shall be the responsibility of the gear manufacturer.

5.3 Final manufacturing schedule- During bid solicitation and evaluation, bidders shall propose a deadline for the final manufacturing schedule (see QP3000). The purchaser shall enforce the deadline.

5.4 Manufacturing schedule audit- The purchaser and gear specialist shall audit the manufacturing schedule for conformance to the procurement specification. See CK7000 for required content of the manufacturing schedule. See QP2000 for guidelines for procurement specifications.

5.5 Manufacturing schedule approval- Manufacturing shall not begin until the purchaser approves the manufacturing schedule. See QP1000 for guidelines covering the procurement process.

5.6 Progress reports- The contact person shall submit progress reports periodically. The manufacturing schedule shall be revised as necessary to make it current with actual progress.

5.7 Coordination- The purchaser shall coordinate manufacturing audits with the manufacturing schedule.

6. Acceptance Criteria

6.1 Format- The manufacturing schedule shall be a Gantt chart.

6.2 Hold and witness points- The manufacturing schedule shall list hold and witness points that are achievable by the purchaser's representative.

6.3 Deadlines- The manufacturing schedule shall list completion dates that are compatible with the purchaser's requirements.

7. Report

7.1 The purchaser shall write a report that includes recommendations for revisions to the manufacturing schedule required for conformance to the procurement specification.

5.8 QP8000 Manufacturing audit

Company Name	QUALITY PROCEDURE	No. QP8000	SHEET 1 OF 3
		Rev. A	
Manufacturing Audit		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

1. Scope

1.1 This Quality Procedure gives overall guidelines for conducting a manufacturing audit. It lists checklists necessary to ensure that all QA certificates are proper and only conforming product is used.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 *(Company)* Specifications:

CK5000	QP5000	Quality assessment
CK6000	QP6000	Quality assurance plan
CK7000	QP7000	Manufacturing schedule
CK8000	QP8000	Manufacturing audit

1.1.1.1.7 CK8200 QP8200 Gear tooth cutting

CK8300	QP8300	Heat treatment of carburized gears
CK8400	QP8400	Gear tooth grinding
CK8500	QP8500	Gear tooth inspection

3. Terminology

3.1 Manufacturing audit- See QP5000.

3.2 Quality assurance certificate- Written documentation of inspection or test results certifying that inspections or tests were performed on actual product, raw material for actual product, coupons, or test specimens.

3.3 Conforming product- Product with certificates proving product was identified, inspected, tested, and found to be conforming to specified requirements.

3.4 Nonconforming product- Product with certificates proving product was identified, inspected, tested, and found to be nonconforming to specified requirements.

Company Name	QUALITY PROCEDURE	No. QP8000	SHEET 2 OF 3
		Rev. A	
Manufacturing Audit		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

4. Significance and Use

4.1 Significance- A manufacturing audit ensures only conforming product is accepted, and quality goals are achieved.

4.2 QA plan- A manufacturing audit determines whether the QA plan is properly conceived, adequately documented, and properly implemented.

5. Procedure

5.1 QA plan- The inspections and tests specified in the QA plan shall be rigorously implemented (see CK8000).

5.2 Manufacturing schedule- The sequence for inspections and tests specified in the manufacturing schedule shall be adhered to (see CK7000 and QP7000).

5.3 Hold points- The hold points specified in the QA plan shall be rigorously enforced.

5.4 Inspected components- All components, as specified in the QA plan, shall be identified, inspected, and tested.

5.5 Conforming product- Only product with QA certificates proving conformance with the QA plan shall be accepted.

5.6 Nonconforming product- Nonconforming product shall be removed from the production area and placed in a controlled area to preclude its use. Nonconforming product shall be reworked or scraped.

5.7 Reworked product- Repairs shall be made with full knowledge of all departments concerned. Reworked product shall be controlled until required inspections and tests are completed. Only conforming product shall be returned to production flow.

5.8 Scraped product- Scraped product shall be mutilated to avoid returning it to production.

5.9 Documentation- All quality assurance records including QA certificates shall be adequately identified, stored, maintained, and distributed. QA records shall be current and readily accessible to the purchaser's representative at any time during manufacturing. Final QA records shall be delivered to the purchaser within the time specified in the procurement specification.

6. Interpretation of results

6.1 QA plan- The results of the manufacturing audit shall be evaluated to determine whether the QA plan is properly conceived, adequately documented, and properly implemented.

6.2 Nonconforming product- The causes of nonconformity shall be investigated, and corrective actions shall be identified.

Company Name	QUALITY PROCEDURE	No. QP8000	SHEET 3 OF 3
		Rev. A	
Manufacturing Audit		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

6.3 Quality goals- The results of the manufacturing audit shall be evaluated to determine whether the QA plan is adequate to achieve the quality goals specified by the procurement specification.

7. Acceptance Criteria

7.1 Quality- All gearbox components shall be conforming product.

7.2 Specification conformance- All gearbox components shall conform to the requirements of the QA plan, engineering specifications, and the procurement specification.

8. Report

8.1 The report shall include the following:

8.1.1 Recommendations for revisions to the QA plan,

8.1.2 Recommendations for revisions to engineering specifications,

8.1.3 Recommendations for revisions to manufacturing processes,

8.1.4 List of nonconforming product including causes of nonconformity and corrective actions and,

8.1.5 Recommendations for follow-up audits to ensure corrective actions are successful.

Company Name	QUALITY PROCEDURE	No. QP8300	SHEET 1 OF 2
		Rev. A	
Heat Treatment of Carburized Gears		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers heat treatment of carburized gears.

2. Referenced Documents

2.1 SAE J415 Definition of Heat Treating Terms.

2.2 ANSI/AGMA 2101-C95 Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth.

2.3 ISO 6336-5 Calculation of Load Capacity of Spur and Helical Gears- Part 5: Strength and Quality of Materials.

2.4 *Company* Specifications:

CK8000	QP8000	Manufacturing audit
CK8300	QP8300	Heat treatment of carburized gears
	QP8301	Procedure for preparing representative test coupons
	QP8302	Inspection of surface hardness
	QP8303	Inspection of case depth
	QP8304	Inspection of core hardness
	QP8305	Inspection of case microstructure
	QP8306	Inspection for carbides
	QP8307	Inspection for decarburization
	QP8308	Inspection for carbon content
	QP8309	Inspection for microcracks
	QP8310	Inspection for secondary transformation products
	QP8311	Inspection for intergranular oxidation
	QP8312	Inspection for retained austenite
	QP8313	Inspection for core microstructure
	QP8314	Procedure for post carburizing cold treatment

Company Name	QUALITY PROCEDURE	No. QP8300	SHEET 2 OF 2
		Rev. A	
Heat Treatment of Carburized Gears		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

3. Terminology

3.1 Definitions- For definition of terms see SAE J415.

3.2 Carburizing- A process in which an austenitized ferrous material is brought into contact with a carbonaceous atmosphere of sufficient carbon potential to cause absorption of carbon at the surface and, by diffusion, create a concentration gradient.

4. Significance and Use

4.1 Application- Carburized gears are used in applications that require maximum load capacity or minimum weight.

4.2 Processing- Carburized gears are first machined, then heated in a carbon atmosphere that causes carbon to diffuse into surface layers of the gear teeth. Gears are hardened by quenching from the carburizing temperature or they are cooled, reheated, and quenched. Tempering where the gears are reheated to a relatively low temperature and slowly cooled follows carburizing and hardening. Distortion is large due to the drastic quench from high temperature. Therefore, gear teeth are finished by grinding to obtain acceptable accuracy.

4.3 Metallurgical quality- Gears should be made from carburizing grade alloy steels with sufficient hardenability to obtain case and core properties meeting the requirements for grade 2 material in accordance with ANSI/AGMA 2101-C95, or quality MQ in accordance with ISO 6336-5.

4.4 Quality control- Unfortunately, there is few nondestructive tests that can be used to check whether carburizing has been successful. Therefore, process control and representative test coupons are required to indirectly control metallurgical quality. This makes it imperative that coupons truly represent gears and all processing be carefully controlled to obtain required metallurgical quality.

4.5 Quality audit- See CK8000 and QP8000 for quidelines for auditing manufacturing. See CK8300 for checklist for heat treatment. See QP8301 through QP8313 for quality procedures for representative test coupons. See QP8314 for procedure for post carburizing cold treatment.

Company Name	QUALITY PROCEDURE	No. QP8301	SHEET 1 OF 3
		Rev. A	
Procedure for Preparing Representative Test Coupons		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers preparation of representative test coupons for use in monitoring heat treatment of carburized gears.

2. Referenced Documents

2.1 ASTM E 3 Standard Practice for Preparation of Metallographic Specimens.

3. Terminology

3.1 Representative test coupon- A coupon designed to represent the cooling rate of the teeth of a particular carburized and hardened gear.

4. Representative Test Coupon

4.1 Raw material- The coupon shall be made from the same heat of steel as the gears it represents.

4.2 Geometry- Diameter shall be six times the module ($6 \times m_n$) and length shall be twice the diameter.

4.3 Machining- Coupon shall be lathe turned to Ra = 3.2 μm maximum surface roughness. Stock removal shall be $0.2 \times m_n$ minimum.

4.4 Traceability- Coupon shall be stamped with an identification number that is traceable to the gear it represents and the heat of steel.

4.5 Heat treatment- The coupon shall be wired to a gear and accompany the gears through all heat treatment including, but not limited to, normalizing, carburizing, quenching, tempering, and post carburize cold treatment.

4.6 Cleaning- After heat treatment, the coupon shall be washed with soap and water, rinsed with methanol, and dried. Grit blasting or other cleaning methods shall not be used.

5. Cutting

5.1 Cutting machine- All cutting shall be done with a water-cooled, abrasive, cut-off wheel. Cut sections shall be nital etched to demonstrate that they have not been tempered.

5.2 Cross-section removal- A 10 mm thick transverse section shall be removed from the midsection of the coupon by cutting in two planes perpendicular to the axis of the coupon as shown in Figure 1.

5.3 Case/core specimens- The cross section shall be cut along the lines marked A, B, and C in Figure 2 to remove one core specimen and three case specimens.

6. Metallurgical Mounts

6.1 Mounting- The core specimen and case specimens shall be mounted in phenolic resin mounts in

accordance with ASTM E 3.

Company Name	QUALITY PROCEDURE	No. QP8301	SHEET 2 OF 3
		Rev. A	
Procedure for Preparing Representative Test Coupons		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

6.2 Traceability- All mounts shall be etched with the identification number of the coupon.

6.3 Grinding and polishing- The core specimen and case specimens shall be ground and polished in accordance with ASTM E 3.

Company Name	QUALITY PROCEDURE	No. QP8301	SHEET 3 OF 3
		Rev. A	
Procedure for Preparing Representative Test Coupons		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

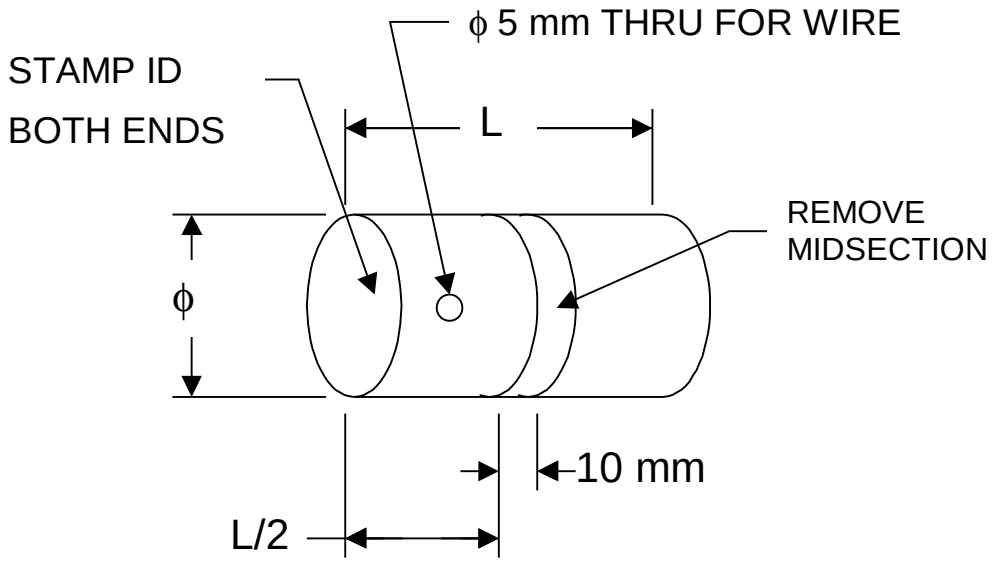


FIGURE 1

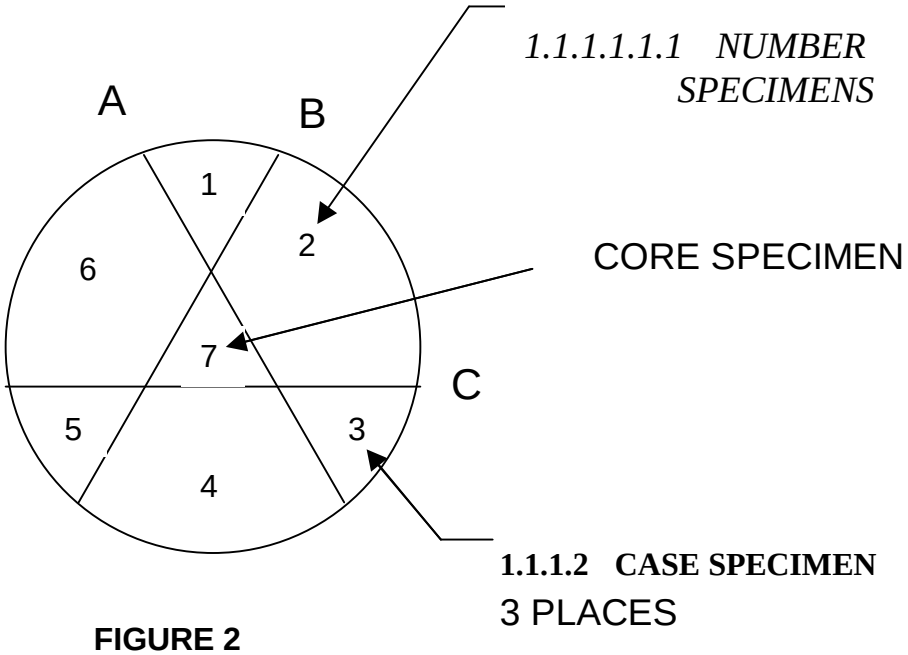


FIGURE 2

Company Name	QUALITY PROCEDURE	No. QP8303	SHEET 1 OF 2
		Rev. A	
Inspection of Case Depth		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers inspection of case depth on representative test coupons for use in monitoring heat treatment of carburized gears.

2. Referenced Documents

2.1 QP8301 Procedure for Preparing Representative Test Coupons

2.2 ASTM E384 Standard Test Method for Microhardness of Materials

3. Terminology

3.1 Representative test coupon- A coupon designed to represent the cooling rate of the teeth of a particular carburized and hardened gear.

3.2 Effective case depth- Distance from the surface of the representative test coupon including oxide scale to where the hardness is 50 HRC by conversion from a microhardness number.

3.3 Effective case depth after grind- Distance obtained by subtracting the material removed during grinding of the gear from the effective case depth.

4. Significance and Use

5. Apparatus

5.1 Microhardness testing machine- Either a Vickers or Knoop test machine shall be used.

5.2 Standardized test block- A test block certified to 58 HRC hardness and traceable to NIST shall be used.

6. Test Specimens

6.1 Representative test coupons- Microhardness tests shall be performed on representative test coupons conforming to QP8301.

7. Procedure

7.1 Indenter load- The indenter load shall be 500 g.

7.2 Verification of test machine- The accuracy and repeatability of the hardness tester shall be verified before and after any hardness survey is made. At each verification, five tests shall be taken on the hardness test block. The average reading shall be in the limits of 57.5 and 58.5 HRC. The range of readings shall be within 57 and 59 HRC

7.3 Calibration of test machine- The hardness tester shall be adjusted to maintain accuracy and repeatability within limits for average and range of readings specified in 7.2 Verification.

Company Name	QUALITY PROCEDURE	No. QP8303	SHEET 2 OF 2
		Rev. A	
Inspection of Case Depth		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

7.4 Depth of first indentation- The first indentation shall be 0.1 mm from the surface including oxide scale.

7.5 Spacing of indentations- Spacing of indentations shall be 0.1 mm.

7.6 Depth of survey- The microhardness survey shall extend to at least twice the effective case depth.

8. Interpretation of Results

8.1 Hardness gradient- The results of the microhardness survey shall be plotted on a graph of hardness versus depth from the surface.

8.2 Effective case depth after grind- The effective case depth after grind shall be determined from the hardness gradient by subtracting the material removed during grinding of the gear from the effective case depth.

8.3 Case hardness- The case hardness shall be determined from the hardness gradient at a depth corresponding to the material removed during grinding of the gear.

9. Acceptance Criteria

9.1 Effective case depth after grind- The effective case depth after grind shall be within the limits specified on the engineering drawing for the gear represented by the representative test coupon.

9.2 Case hardness- The case hardness shall be 58-62 HRC after conversion from a microhardness number.

9.3 Hardness difference- The hardness difference between the surface hardness and the maximum hardness below the surface shall not exceed 2 HRC after conversion from a microhardness number.

10. Report

10.1 The report shall include the following:

10.1.1 Description of the microhardness test machine,

10.1.2 Indenter load,

10.1.3 Graph of microhardness survey,

10.1.4 Effective case depth after grind,

10.1.5 Case hardness, and

10.1.6 Hardness difference between surface and maximum value.

Company Name	QUALITY PROCEDURE	No. QP8304	SHEET 1 OF 3
		Rev. A	
Inspection of Core Hardness		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers inspection of core hardness on representative test coupons for use in monitoring heat treatment of carburized gears.

2. Referenced Documents

2.1 AGMA/AWEA 921-A97 Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems.

2.2 ASTM E18 Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials.

2.3 GEARTECH Specifications:

CK8301 QP8301 Procedure for preparing representative test coupons

3. Terminology

3.1 Representative test coupon- A coupon designed to represent the cooling rate of the teeth of a particular carburized and hardened gear.

3.2 Core hardness- Rockwell hardness measured on the core specimen.

3.3 Core specimen- The specimen defined in Figure 2 of QP8301.

3.4 Specified core hardness- Hardness limits specified on the engineering drawing for the gear represented by the representative test coupon.

4. Significance and Use

4.1 Load capacity- Core hardness must be maintained within specified core hardness to achieve adequate fatigue strength and fracture toughness.

4.2 Process control- Core hardness varies with material hardenability, quench severity, and heat treat process. Core hardness measurements are useful for monitoring process control.

5. Apparatus

5.1 Hardness testing machine- A Rockwell® test machine in accordance with ASTM E18 shall be used.

5.2 Standardized test block- A test block in accordance with ASTM E18 and traceable to NIST shall be used. The test block shall be of certified hardness equal to the mid-range of the specified core hardness $\pm$ 4 HRC.

6. Test specimens

6.1 Core specimen- Hardness tests shall be performed on core specimens from representative test coupons conforming to QP8301.

Company Name	QUALITY PROCEDURE	No. QP8304	SHEET 2 OF 3
		Rev. A	
Inspection of Core Hardness		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

7. Procedure

7.1 Specification conformance- The test procedure and test apparatus shall conform to ASTM E18.

7.2 Indenter- The indenter shall be a Brale® diamond penetrator.

7.3 Indenter load- The major load shall be 150-kgf (1471 N).

7.4 Inspection of indenter- The indenter shall be inspected with a microscope. There shall be no damage to the indenter tip visible at 30X magnification.

7.5 Verification of test machine- The accuracy and repeatability of the hardness tester shall be verified before and after any hardness test is made. At each verification, five tests shall be taken on the hardness test block. The error and repeatability of the test machine shall be determined in accordance with ASTM E18.

7.6 Calibration of test machine- If the error of the test machine exceeds $\pm$ 2 HRC it shall be adjusted. The test machine shall be considered calibrated when its error $\leq \pm$ 2 HRC and its repeatability $\leq$ 2 HRC.

7.7 Number of indentations- At least three hardness readings shall be made.

7.8 Spacing of indentations- Spacing shall be in accordance with ASTM E18.

7.9 Load application time- The major load shall be applied for at least 5 seconds after the operating lever stops.

8. Interpretation of results

8.1 Scale reading- Readings shall be estimated to one tenth of a division.

8.2 Core hardness- The core hardness shall be calculated as the mean of the measurements.

8.3 Rounding- The core hardness shall be rounded to the nearest integer. For example, a mean of 35.5 shall be reported as 36 HRC and a mean of 35.4 shall be reported as 35 HRC.

9. Acceptance criteria

9.1 Core hardness- The core hardness shall conform to the specified core hardness.

10. Report

10.1 The report shall include the following:

10.1.1 Serial number of the test machine,

10.1.2 Serial number of the standardized test block,

Company Name	QUALITY PROCEDURE	No. QP8304	SHEET 3 OF 3
		Rev. A	
Inspection of Core Hardness		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

10.1.3 Identification number of representative test coupon,

10.1.4 Indenter load,

10.1.5 Load application time, and

10.1.6 Core hardness.

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 1 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers inspection of gear tooth accuracy with gear tooth inspection machines.

2. Referenced Documents

2.1 ANSI/AGMA 2000-A88 Gear Classification and Inspection Handbook.

2.2 ANSI/AGMA 2010-A94 Measuring Instrument Calibration – Part I, Involute Measurement.

2.3 ANSI/AGMA 2113-A97 Measuring Instrument Calibration, Gear Tooth Alignment Measurement.

2.2 ANSI/AGMA ISO 1328-1 Cylindrical Gears- ISO System of Accuracy- Part 1: Definitions and Allowable Values of Deviations Relevant to Corresponding Flanks of Gear Teeth.

3. Terminology

3.1 Definitions- For definitions of terms see ANSI/AGMA 2000-A88 or ANSI/AGMA ISO 1328-1 as appropriate.

3.2 Definitions of terms specific to this Quality Procedure:

3.2.1 Active Flank- The flank that is loaded in service.

3.2.2 Left Hand Helix- A helix that runs in the sense of a left-hand screw thread. Figure 3 shows an internal gear with a left-hand helix.

3.2.3 Left Flank- Looking in the view direction, the left flank bounds the left side of the tooth, when the tooth is viewed with the tip above the root.

3.2.4 Right Flank- Looking in the view direction, the right flank bounds the right side of the tooth, when the tooth is viewed with the tip above the root.

3.2.5 Right Hand Helix- A helix that runs in the sense of a right-hand screw thread. Figure 1 shows an external gear with a right-hand helix.

3.2.6 Datum Axis- The axis about which the gear rotates during inspection of gear tooth accuracy. The datum axis shall match the functional axis as closely as possible. This is best achieved by using functional mounting surfaces as the datum surfaces.

3.2.7 Functional Axis- The axis about which the gear rotates in service. It is defined by the centers of the functional mounting surfaces.

3.2.8 Reference Face- For symmetrical gears, one face shall be identified with a permanent, unique mark or other unique feature.

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 2 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

3.2.9 Evaluation length- That part of the usable length to which the tolerances of the specified accuracy class shall apply. Unless otherwise specified, the evaluation length for a profile chart shall extend from MAX CHAM to PCD, and the evaluation length for a tooth alignment chart shall extend for the central 90% of the face width.

3.2.10 MIN CHAM- Position on the profile chart corresponding to the maximum tip radius minus the minimum tip chamfer.

3.2.11 MAX CHAM- Position on the profile chart corresponding to the minimum tip radius minus the maximum tip chamfer.

3.2.12 MOD- Position on the profile chart corresponding to the start of tip or root relief.

3.2.13 HPSTC- Position on the profile chart corresponding to the highest-point-of-single-tooth-contact.

3.2.14 LPSTC- Position on the profile chart corresponding to the lowest-point-of-single-tooth-contact.

3.2.15 SAP- Position on the profile chart corresponding to the start-of-active-profile.

3.2.16 PCD- Position on the profile chart corresponding to the profile control diameter.

4. Significance and Use- Unless otherwise specified, all gears shall meet the accuracy requirements for AGMA quality No. Q11 in accordance with ANSI/AGMA 2000-A88. The gear quality is an indication of geometric accuracy of the gear. The higher the quality the higher the load capacity and the lower the noise level.

4.1 Application- This quality procedure applies to ground gears.

5. Apparatus

5.1 Gear teeth shall be inspected on a mechanical or computer numerically controlled (CNC) gear tooth inspection machine. Gear tooth inspections shall not be done on the gear tooth grinding machine.

6. Test Specimens

6.1 Gears- Accuracy measurements shall be performed on gear teeth after all grinding is completed.

7. Procedure

7.1 Temperature- Temperature in the immediate area of the inspection machine shall be 20°C ± 2°C.

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 3 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

7.2 Verification- The accuracy and repeatability of the accuracy inspection machine shall be verified before any group of gears is inspected. At each verification, profile, tooth alignment, and pitch shall be checked on an artifact. Measured accuracy shall be within 2μm of the known dimension of the artifact.

7.3 Calibration- The inspection machine shall be adjusted to maintain accuracy and repeatability within limits specified in 7.2 Verification and as specified by ANSI/AGMA 2010-A94 and ANSI/AGMA 2113-A97.

7.4 Setup- Gears shall be setup in the gear inspection machine such that runout of datum (functional) surfaces is easily measured.

7.4.1 Gears shall be inspected on the shafts they will operate on.

7.4.2 Runout of datum (functional) surfaces shall be recorded.

7.4.3 Teeth shall be identified as shown in Figure 2 or 4 and be numbered permanently.

7.4.4 Reference face shall be identified as shown in Figure 1 or 2 and be numbered permanently.

7.4.5 Number of teeth inspected- Unless otherwise specified, profile and helix alignment shall be measured on the active flanks of four teeth equally spaced around the gear. Pitch shall be measured on all teeth.

7.4.6 Measurement Position- Unless otherwise specified, measurements shall be made near midface for profiles, along the pitchline for helix alignment, and near midface and pitchline for pitch.

7.5 Profile and tooth alignment chart annotations- All charts shall include the following:

7.5.1 Inspectors stamp and date.

7.5.2 Serial number of gear inspected.

7.5.3 Sketch of gear orientation in the inspection machine showing direction of helix, top of gear, view direction, and reference face (for symmetrical gears) as shown in Figure 1 or 3.

7.5.4 Sketch of end view of at least two teeth showing left/right flank designation, active flank designation, and tooth numbering convention as shown in Figure 2 or 4. End view shall be consistent with view direction specified in 7.5.3.

7.5.5 Table showing number of teeth (z), normal module (m_n), normal pressure angle (α), helix angle (β), face width (b), and hand of helix.

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 4 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

7.6 Profile chart annotations- All profile charts shall include the following annotations:

7.6.1 Tooth numbers of teeth inspected.

7.6.2 Left /right flank designation, active flank, and tip or root.

7.6.3 Magnification of chart in horizontal and vertical directions.

7.6.4 Base tangent lengths, roll angles or diameters corresponding to the following:

7.6.4.1 MIN CHAM, MAX CHAM,

7.6.4.2 MOD, HPSTC, LPSTC, SAP and PCD.

7.6.4.3 Evaluation length.

7.7 Tooth Alignment Chart Annotations- All tooth alignment charts shall include the following annotations:

7.7.1 Tooth numbers of teeth inspected.

7.7.2 Left/right flank designation, active flank, and top of gear consistent with Section 7.5.3.

7.7.3 Magnification of chart in horizontal and vertical directions.

7.7.4 Start of helix modifications.

7.7.5 Evaluation length.

8. Interpretation of Results

8.1 Accuracy- Accuracy of profile, tooth alignment, pitch, and runout shall be determined in accordance with ANSI/AGMA 2000-A88 or ANSI/AGMA ISO 1328-1 as specified on the engineering drawing for the gear.

8.2 Profile and helix modifications- Accuracy of profile and helix modifications shall be determined in accordance with the engineering drawing for the gear.

9. Acceptance Criteria

9.1 Accuracy- The accuracy class shall be determined from the maximum variation of profile, tooth alignment, or pitch for any one tooth, or runout for all teeth. The accuracy shall be within the AGMA or ISO accuracy class specified on the engineering drawing for the gear.

9.2 Profile and helix modifications- Location and magnitude of modifications shall be within the tolerances specified on the engineering drawing for the gear.

10. Report

10.1 The report shall include the following:

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 5 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

10.1.1 Description of the accuracy inspection machine.

10.1.2 Profile charts.

10.1.3 Tooth alignment charts.

10.1.4 Pitch charts.

10.1.5 Accuracy class.

10.1.6 Records of calibrations.

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 6 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

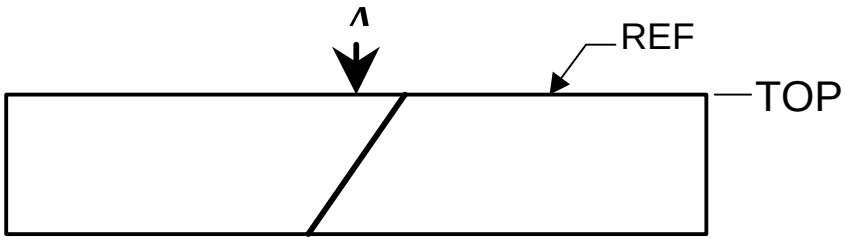


FIGURE 1

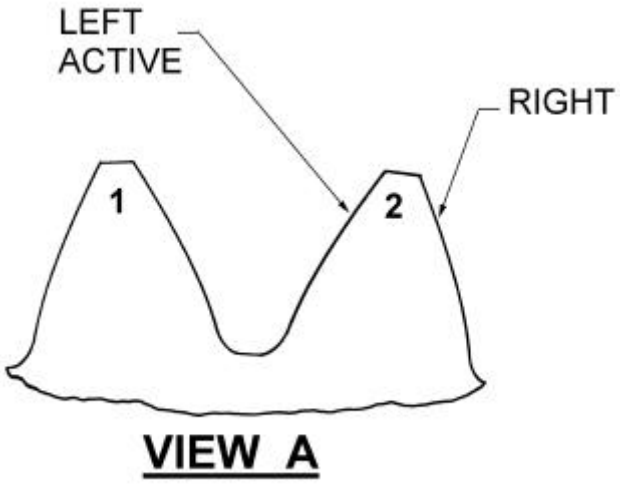


FIGURE 2

Company Name	QUALITY PROCEDURE	No. QP8502	SHEET 7 OF 7
		Rev. A	
Procedure for Inspection of Gear Tooth Accuracy		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

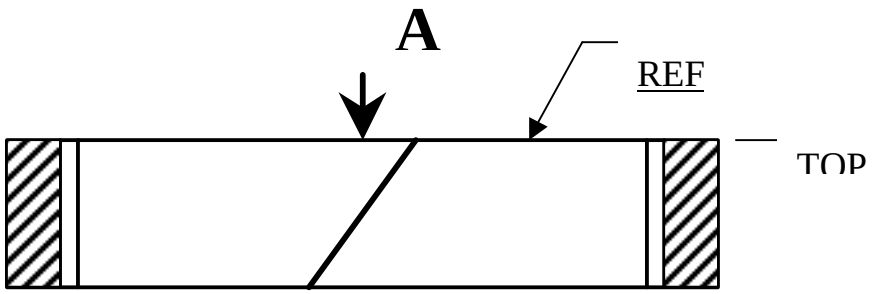
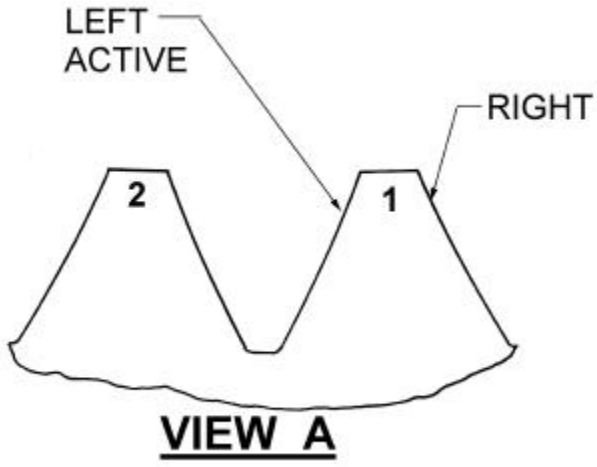


FIGURE 3



1.1.1.2 **FIGURE 4**

Company Name	QUALITY PROCEDURE	No. QP8508	SHEET 1 OF 2
		Rev. B	
Procedure for Inspection of Gear Tooth Surface Hardness		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

1. Scope

1.1 This procedure covers inspection of gear tooth surface hardness with portable hardness testers.

2. Referenced Documents

2.1 ASTM E110 Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers.

2.2 ASTM A956 Standard Test Method for Equotip Hardness Testing of Steel Products.

3. Terminology

3.1 Surface hardness-

4. Significance and Use

4.1 Application-

5. Apparatus

5.1 Hardness tester- Either a Microdur or an Equotip hardness tester shall be used.

5.2 Hardness test block- A test block certified to 58 HRC hardness and traceable to NIST shall be used.

6. Test Specimens

6.1 Gears- Hardness tests shall be performed on gear teeth after all grinding is completed.

7. Procedure

7.1 Readout Scale- Readout shall be displayed in Rockwell C (HRC) units.

7.2 Verification- The accuracy and repeatability of the hardness tester shall be verified before and after any series of hardness measurements are made. At each verification, five tests shall be taken on the hardness test block. The average reading shall be within the limits of 57.5 and 58.5 HRC. The range of readings shall be within 57 and 59 HRC.

7.3 Calibration- The hardness tester shall be adjusted to maintain accuracy and repeatability within limits for average and range of readings specified in 7.2 Verification.

8. Interpretation of Results

8.1 Rounding- Readings shall be rounded to nearest integer. For example, a reading of 57.5 shall be reported as 58 HRC and a reading of 57.4 shall be reported as 57 HRC.

Company Name	QUALITY PROCEDURE	No. QP8508	SHEET 2 OF 2
		Rev. B	
Procedure for Inspection of Gear Tooth Surface Hardness		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

9. Acceptance Criteria

9.1 Minimum Hardness- Minimum hardness shall be 58 HRC. If any reading is less than 58 HRC, three additional readings shall be taken within 3 mm of the low reading. The average of the three additional readings shall be 58 HRC minimum after rounding per 8.1 Rounding. Otherwise, the gear is rejectable.

9.2 Maximum Hardness- Maximum hardness shall be in accordance with drawing specification.

10. Report

10.1 The report shall include the following:

10.1.1 Description of the hardness test machine.

10.1.2 Minimum surface hardness.

10.1.3 Maximum surface hardness.

10.1.4 Records of calibrations

Gearbox Quality Checklists

Checklists are an effective way of verifying that critical steps have been completed in a long and complicated process. They can serve as evidence that a quality system exists and being used. They can also help assure repeatable results in a multi-step process. Finally they can be a way of communicating technical information succinctly. The following checklists are compliments to the quality procedures (QP) presented in section 5. For each QP there is a complimentary CK (checklist). Once again they are intended to be used and customized to suite the manufacturers purposes.

5.9 CK1000 Procurement process

Company Name	CHECKLIST	No. CK1000	SHEET 1 OF 5
		Rev. A	
Procurement Process		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

PROCUREMENT SPECIFICATION

Question	Y	N	R	Comments
Has a procurement specification been written?				
Does the procurement specification include all items listed in CK2000?				
Has a person been assigned to ensure the procurement specification is implemented and maintained?				
Are there procedures for distributing the procurement specification?				
Are there procedures for revising the procurement specification?				

WORKING WITH BIDDERS

Question	Y	N	R	Comments
Do bidders have experience necessary to produce gearboxes that conform to requirements of the procurement specification?				
Do bidders have capabilities necessary to produce gearboxes that conform to requirements of the procurement specification?				
Do bidders understand the procurement specification?				
Did bidders submit complete proposals including:				
Completed questionnaire?				
List of exceptions to the procure-				

ment specification?				

Company Name	CHECKLIST	No. CK1000	SHEET 2 OF 5
		Rev. A	
Procurement Process		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

WORKING WITH BIDDERS (continued)

Question	Y	N	R	Comments
Preliminary QA plan?				
Preliminary manufacturing schedule?				
Preliminary layout (assembly) drawing of gearbox?				
Preliminary outline dimension drawing of gearbox?				
Gear data?				
Bearing data?				
Load/life calculations?				
Lubrication data?				

EVALUATE PROPOSALS

Question	Y	N	R	Comments
Have bidder proposals been evaluated for completeness and conformance to the procurement specification?				
Have the best proposals been selected?				
Are bidders with the best proposals prepared to attend design review meetings?				
Do the best proposals meet the following criteria:				
Exceptions to the procurement specification acceptable?				
Preliminary QA plan acceptable?				
Preliminary manufacturing schedule acceptable?				

Company Name	CHECKLIST	No. CK1000	SHEET 3 OF 5
		Rev. A	
Procurement Process		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

EVALUATE PROPOSALS (continued)

Question	Y	N	R	Comments
Preliminary design meet requirements of the procurement specification?				

DESIGN REVIEW MEETINGS

Question	Y	N	R	Comments
Have design review meetings been held with each of the bidders with best proposals?				

AWARDING CONTRACT

Question	Y	N	R	Comments
Has the bidder with the best proposal been selected as the gear manufacturer?				
Has the gear manufacturer been audited for conformance to CK5000?				
Has the final gearbox design been audited by a gear specialist?				
Has the contract been awarded?				
Does gear manufacturer understand that manufacturing shall not commence until the purchaser approves the engrg drawings, QA plan, and manufacturing schedule?				

AUDIT DETAIL DRAWINGS

Question	Y	N	R	Comments
Has the gear manufacturer submitted all data required by CK4000?				

Company Name	CHECKLIST	No. CK1000	SHEET 4 OF 5
		Rev. A	
Procurement Process		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

AUDIT DETAIL DRAWINGS (continued)

Question	Y	N	R	Comments
Has all data submitted by the gear manufacturer been reviewed by a gear specialist?				
Have the engineering drawings been reviewed by a gear specialist?				
Have the engineering drawings been approved by the purchaser?				

AUDIT QA PLAN

Question	Y	N	R	Comments
Does the gear manufacturer's QA plan conform to CK6000?				
Has the final QA plan been audited by a gear specialist?				
Has the final QA plan been approved by the purchaser?				

AUDIT MANUFACTURING SCHEDULE

Question	Y	N	R	Comments
Does the gear manufacturer's MFG schedule conform to CK7000?				
Has the final MFG schedule been audited by a gear specialist?				
Has the final MFG schedule been approved by the purchaser?				

AUDIT MANUFACTURING

Question	Y	N	R	Comments
Has gear manufacturing been audited for conformance to CK8000?				

Company Name	CHECKLIST	No. CK1000	SHEET 5 OF 5
		Rev. A	
Procurement Process		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

AUDIT START UP

Question	Y	N	R	Comments
Has startup been audited for conformance to CK9000?				

5.10 CK2000 Procurement specification

Company Name	CHECKLIST	No. CK2000	SHEET 1 OF 4
		Rev. A	
Procurement Specification		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

Question	Y	N	R	Comments
Does the procurement specification conform to the following requirements of AGMA/AWEA 921-A97, clauses:				
4.1 Specification introduction?				
4.2 System specification?				
4.2.1 Rotor speed?				
4.2.2 Gear ratio?				
4.2.3 Loading?				
4.2.4 Configuration?				
4.2.5 Operating environment?				
4.2.6 Sound?				
4.2.7 Vibration?				
4.2.8 Control?				
4.2.9 Start-up considerations?				
4.3 Component rating?				
4.3.1 Gear life rating?				
4.3.2 Gearbox thermal rating?				
4.3.3 Bearing life rating?				
4.3.4 Shaft life rating?				
4.3.5 Housings?				
4.3.6 Seals?				
4.4 Gear elements?				
4.4.1 Gear type?				
4.4.2.1 Preferred number of pinion teeth?				

Company Name	CHECKLIST	No. CK2000	SHEET 2 OF 4
		Rev. A	
Procurement Specification		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

Question	Y	N	R	Comments
4.4.2.3 Total contact ratio?				
4.4.2.4 Profile shift?				
4.4.2.5 Profile modification?				
4.4.2.6 Helix modification?				
4.4.3 Gear materials?				
4.4.3.1 External gears?				
4.4.3.2 Internal gears?				
4.4.4 Gear accuracy?				
4.4.5 Gear manufacturing				
4.4.5.1 Gear tooth cutting?				
4.4.5.2 Gear tooth grinding?				
4.4.5.3 Gear tooth chamfering?				
4.4.5.4 Gear tooth surface roughness?				
4.4.6 Gear arrangements?				
4.4.7 Lifting holes?				
4.5 Bearings?				
4.5.1 Bearing type?				
4.5.2 Bearing arrangement?				
4.5.3 Bearing shaft/housing fits?				
4.6 Shaft and keys?				
4.6.1 Shafts?				
4.6.3 Shaft hardness?				
4.6.4 Lifting holes?				
4.6.5 Keys?				
4.6.6 Key material?				

Company Name	CHECKLIST	No. CK2000	SHEET 3 OF 4
		Rev. A	
Procurement Specification		BY*: Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

Question	Y	N	R	Comments
4.6.8 Key geometry and shaft fit?				
4.7 Housings?				
4.7.1 Housing material?				
4.7.2 Housing distortion?				
4.7.3 Housing accuracy?				
4.7.4 Inspection covers?				
4.7.5 Bore covers?				
4.7.6 Housing joint?				
4.8 Lubrication system?				
4.8.1 Type of lubricant?				
4.8.2 Lubricant viscosity?				
4.8.3 Method of lubrication?				
4.8.4 Sump temperature?				
4.8.5 Operating temperature?				
4.8.6 Orifices?				
4.8.6.1 Drain and fill plugs?				
4.8.6.2 Pressurized ports?				
4.8.6.3 Non-pressurized ports?				
4.8.7 Oil level indicator?				
4.8.9 Breather?				
4.9 Seals?				
4.10 Interfaces?				
4.10.1 Low speed shaft?				
4.10.2 High speed shaft(s)?				
4.10.3 Mounting?				
4.10.4 Torque arm?				

Company Name	CHECKLIST	No. CK2000	SHEET 4 OF 4
		Rev. A	
Procurement Specification		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

Question	Y	N	R	Comments
4.10.5 Generator?				
4.10.6 Pitch system?				
4.10.7 Yaw system?				
4.10.8 Lifting points?				
4.10.9 Brake?				
4.10.10 Sensors?				
4.10.11 Safety systems?				
4.10.12 Personnel?				
4.10.13 Miscellaneous?				
4.11 Hardware?				
4.11.1 High strength hardware?				
4.11.2 Internal fasteners?				
4.12 Surface coatings?				
4.13 Quality assurance?				
4.14 Analysis, drawings and data?				

5.11 CK3000 Bid solicitation and evaluation

Company Name	CHECKLIST	No. CK3000	SHEET 1 OF 2
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	DATE *(date written)*
		CKD *Checker*	DATE *(date checked)*

BID SOLICITATION

Question	Y	N	R	Comments
Has a request for a proposal been written?				
Does the request for proposal include a procurement specification per QP2000?				
Does the request for proposal include bidding instructions per QP3000?				
Has a person been assigned to ensure the request for proposal is implemented and maintained?				
Are there procedures for distributing the request for proposal?				
Are guidelines for the procurement process (CK1000 and QP1000) being followed?				
Are guidelines for bid solicitation and evaluation (QP3000) being followed?				
Is bid solicitation and evaluation complete as follows:				
Request for proposal sent to bidders?				

BID EVALUATION

Question	Y	N	R	Comments
Proposals received from bidders?				
Proposals evaluated for completeness per CK1000?				

Company Name	CHECKLIST	No. CK3000	SHEET 2 OF 2
		Rev. A	
Bid Solicitation and Evaluation		BY: *Author*	DATE *(date written)*
		CKD *Checker*	DATE *(date checked)*

BID EVALUATION(continued)

Question	Y	N	R	Comments
Proposals evaluated for conformance to the procurement specification per CK1000 through CK7000 and QP1000 through QP7000?				
Proposals evaluated by gear specialist?				

5.12 CK4000 Gearbox design audit

Company Name	CHECKLIST	No. CK4000	SHEET 1 OF 1
		Rev. A	
Gearbox Design Audit		BY *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

PROPOSAL DATA

Question	Y	N	R	Comments
Does the proposal include the following documents:				
Load spectrum?				
Outline dimension drawing?				
Assembly drawing?				
Assembly bill of material?				
Lubrication schematic?				
Lube system bill of material?				
Detail drawings of gears?				
Detail drawings of shafts?				
Detail drawing of housing?				
Does the proposal include the following bearing data:				
Manufacturer?				
Type?				
Catalog number?				
Retainer type?				
Retainer material?				
Internal clearance?				

GEAR CALCULATIONS

Question	Y	N	R	Comments
Does the proposal include the following gear calculations:				
Pitting resistance?				
Bending fatigue resistance?				

Company Name	CHECKLIST	No. CK4000	SHEET 1 OF 3
		Rev. A	
Gearbox Design Audit		BY *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

GEAR CALCULATIONS (continued)

Question	Y	N	R	Comments
Scuffing resistance?				
Load capacity of shaft fits?				

BEARING CALCULATIONS

Question	Y	N	R	Comments
Does the proposal include the following bearing calculations:				
Shaft fits?				
Housing fits?				
Life rating calculations?				

SHAFT CALCULATIONS

Question	Y	N	R	Comments
Does the proposal include the following shaft calculations:				
Stresses?				
Deflections?				
Fatigue resistance of-shaft/splines/keyways?				
Ultimate load capacity of shaft/splines/keyways?				

HOUSING CALCULATIONS

Question	Y	N	R	Comments
Does the proposal include the following housing calculations:				
Stresses?				
Deflections?				
Fatigue resistance?				

Company Name	CHECKLIST	No. CK4000	SHEET 2 OF 3
		Rev. A	
Gearbox Design Audit		BY *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

HOUSING CALCULATIONS (continued)

Question	Y	N	R	Comments
Ultimate load capacity?				
Material grade?				
Heat treatment?				
Surface hardness?				
Effective case depth after grind?				
Core hardness?				
Magnetic particle inspection?				
Surface temper etch inspection?				

GEAR RATING CALCULATIONS

Question	Y	N	R	Comments
Are reasonable values chosen for the following parameters:				
Load spectrum?				
Material grade?				
Gear tooth accuracy?				
Surface hardness?				
Load distribution factor, C_m?				
Dynamic factor, C_v?				
Gear tooth temperature?				
Lubricant dynamic viscosity?				
Lubricant pressure-viscosity coefficient?				
Gear tooth surface roughness?				
Gear tooth coefficient of friction?				
Are Miner's Rule lives adequate?				

Company Name	CHECKLIST	No. CK4000	SHEET 3 OF 3
		Rev. A	
Gearbox Design Audit		BY *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

GEAR RATING CALCULATIONS (continued)

Question	Y	N	R	Comments
Adequate life?				
Pinions have at least 20 teeth?				
Profile shift designed for balanced specific sliding?				
Aspect ratio ≤ 1.0 for single helical?				
Aspect ratio ≤ 2.0 for double helical?				
Profiles modified?				
Helices modified?				
Transverse contact ratio ≥ 1.4?				
Axial contact ratio ≥ 1.0?				
Accuracy ≥ AGMA Q =11?				

DESIGN CONTROL

Question	Y	N	R	Comments

Company Name	CHECKLIST	No. CK4100	SHEET 1 OF 4
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

GEAR GEOMETRY

Question	Y	N	R	Comments
Do gear drawings specify the following data:				
z = number of teeth?				
m_n = normal module?				
α_n = normal pressure angle?				
β = helix angle?				
Helix hand?				
a_w = operating center distance?				
b = face width?				
d_a = tip diameter?				
x = profile shift coefficient?				
W_k = span measurement?				
k = number of teeth spanned?				
Tip chamfer?				
End round?				
Edge round?				
Profile modification?				
Helix modification?				

GEAR GEOMETRIC QUALITY

Question	Y	N	R	Comments
Do gear drawings specify the following data:				
Accuracy specification (DIN, ISO, or AGMA)?				
Accuracy class?				
Profile total deviation, F_α?				

Company Name	CHECKLIST	No. CK4100	SHEET 2 OF 4
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

GEAR GEOMETRIC QUALITY (continued)

Question	Y	N	R	Comments
Profile slope deviation, $f_{H\alpha}$?				
Profile form deviation, $f_{f\alpha}$?				
Total helix deviation, F_{β}?				
Helix slope deviation, $f_{H\beta}$?				
Helix form deviation, $f_{f\beta}$?				
Single pitch deviation, f_{pt}?				
Total cumulative pitch deviation, F_p?				
Runout, F_r?				
Reference datum for radial runout?				
Reference datum for axial runout?				
Tolerance for radial runout?				
Tolerance for axial runout?				
Profile tolerance chart?				
Helix tolerance chart?				
Gear tooth surface roughness?				

GEAR METALLURGICAL QUALITY

Question	Y	N	R	Comments
Do gear drawings specify the following data:				
Material form (forging or bar stock)?				
Material alloy?				
Material grade?				
Heat treatment?				
Surface hardness?				
Effective case depth after grind?				

Company Name	CHECKLIST	No. CK4100	SHEET 3 OF 4
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

GEAR METALLURGICAL QUALITY (continued)

Question	Y	N	R	Comments
Core hardness?				
Magnetic particle inspection?				
Surface temper etch inspection?				

GEAR RATING CALCULATIONS

Question	Y	N	R	Comments
Are reasonable values chosen for the following parameters:				
Load spectrum?				
Material grade?				
Gear tooth accuracy?				
Surface hardness?				
Load distribution factor, C_m?				
Dynamic factor, C_v?				
Gear tooth temperature?				
Lubricant dynamic viscosity?				
Lubricant pressure-viscosity coefficient?				
Gear tooth surface roughness?				
Gear tooth coefficient of friction?				
Are Miner's Rule lives adequate?				
Do gears conform to AGMA/AWEA 921:				
Adequate life?				
Pinions have at least 20 teeth?				
Profile shift designed for balanced specific sliding?				

Company Name	CHECKLIST	No. CK4100	SHEET 4 OF 4
		Rev. A	
Gear Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

GEAR RATING CALCULATIONS (continued)

Question	Y	N	R	Comments
Aspect ratio ≤ 1.0 for single helical?				
Aspect ratio ≤ 2.0 for double helical?				
Profiles modified?				
Helices modified?				
Transverse contact ratio ≥ 1.4?				
Axial contact ratio ≥ 1.0?				
Accuracy ≥ AGMA Q =11?				

DESIGN CONTROL

Question	Y	N	R	Comments

Company Name	CHECKLIST	No. CK4200	SHEET 1 OF 3
		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

BEARING DATA

Question	Y	N	R	Comments
Do drawings specify the following data?				
Bearing manufacturer?				
Bearing type?				
Bearing size?				
Bearing retainer material?				
Bearing internal clearance?				
Shaft diameter, surface roughness, and tolerances for inner race fit?				
Housing diameter, surface roughness, and tolerances for outer race fit?				
Boundary dimensions?				
Only two (2) bearings per shaft?				

ASSEMBLY

Question	Y	N	R	Comments
Has gearbox assembly been reviewed to assess risk of damage to bearing components?				
Are there procedures for blind assembly?				
Are there assembly procedures for separable, cylindrical-roller bearings?				
Are shaft-to-inner race fits tight?				
Are housing-to-outer race fits tight?				
If housing-to-outer race fits are loose, are anti-rotation devices specified?				

Company Name	CHECKLIST	No. CK4200	SHEET 2 OF 3
		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

ASSEMBLY (continued)

Question	Y	N	R	Comments
Are internal clearances per bearing manufacturers recommendations?				
Are boundary dimensions per bearing manufacturers recommendations?				
Are bearings free to move axially?				
If necessary, are fixtures for assembly available?				
Is it possible to set proper endplays?				
Will endplays be recorded?				
Have bearing types and arrangements been reviewed to account for thermal growth?				

BEARING RATING CALCULATIONS

Question	Y	N	R	Comments
Are the following factors taken as unity (1.0) for L10 life rating?				
Reliability?				
Material?				
Environment?				
Is life adjustment factor a_1 = 0.21 for L1 life rating?				
Is life adjustment factor a_{23} consistent with oil filtration and actual oil cleanliness?				
Is operating temperature of rolling elements and raceways ≥ 80°C?				
Does ISO viscosity grade conform to AGMA/AWEA 921-A97?				

Company Name	CHECKLIST	No. CK4200	SHEET 3 OF 3
		Rev. A	
Bearing Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

BEARING RATING CALCULATIONS (continued)

Question	Y	N	R	Comments
Does oil cleanliness conform to AGMA/AWEA 921-A97?				
Does operating viscosity correspond to operating temperature?				
Is minimum operating load adequate to prevent skidding between rolling elements and raceways?				
Are axial loads within thrust capacity of C-R bearings?				
Are Miner's Rule lives adequate?				

AGMA/AWEA 921-A97 CONFORMANCE

Question	Y	N	R	Comments
Do bearings conform to AGMA/AWEA 921:				
Adequate life?				
Bearing type?				
Bearing arrangement?				
Bearing shaft/housing fits?				
Bearing retainers?				
Bearing internal clearance?				
Bearing assembly?				
Methods of lubrication?				
Planet gear rim thickness?				

Company Name	CHECKLIST	No. CK4300	SHEET 1 OF 3
		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

SHAFT DATA

Question	Y	N	R	Comments
Do drawings specify the following data?				
Shaft dimensions?				
Shaft material?				
Shaft hardness?				
Are the following geometric tolerances specified?				
Diameters?				
Lengths?				
Surface roughness?				
Straightness?				
Circularity?				
Parallelism?				
Radial and axial runout?				
Do fillets clear mating components and minimize stress concentrations?				
Are keys fitted with an interference fit?				
Are keyways designed to minimize stress concentrations?				
Do inside corners of keyways have adequate fillet radii?				
Are edges of keyways deburred or chamfered?				
Do keyways not extend into bearing journals?				

Company Name	CHECKLIST	No. CK4300	SHEET 2 OF 3
		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

SHAFT DATA (continued)

Question	Y	N	R	Comments
Is shaft material an alloy steel with sufficient hardenability to meet requirements of AGMA/AWEA 921-A97 and procurement specification?				

ASSEMBLY

Question	Y	N	R	Comments
Has gearbox assembly been reviewed to assess risk of damage to shaft?				
Are shaft-to-inner race fits tight?				
If necessary, are fixtures for assembly available?				

SHAFT RATING CALCULATIONS

Question	Y	N	R	Comments
Have shafts been rated per ANSI/AGMA 6001-D97?				
Is reliability factor kc = 0.817?				
Is fatigue safety factor Fsf ≥ 1.1?				
Is peak load safety factor Fsp ≥ 1.1?				
Is slip torque calculated using peak load?				
Is coefficient of friction f ≤ 0.15?				
Are benefits from keys ignored when calculating torque capacity?				
Are fits for shafts and gears calculated from drawing tolerances?				
Is slip torque adequate to transmit peak load?				

Company Name	CHECKLIST	No. CK4300	SHEET 3 OF 3
		Rev. A	
Shaft Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

SHAFT RATING CALCULATIONS (continued)

Question	Y	N	R	Comments
Is deflection calculated using minimum fatigue load?				
Is maximum deflection consistent with load distribution factors?				
Is maximum slope at bearings within bearing manufacturer recommendations?				

AGMA/AWEA 921-A97 CONFORMANCE

Question	Y	N	R	Comments
Do shafts conform to AGMA/AWEA 921:				
Adequate life?				
Geometric quality?				
Fillets?				
Keyways?				
Metallurgical quality?				
Fatigue safety factor?				
Yield safety factor?				
Shaft/gear slip torque?				
Deflection?				

Company Name	CHECKLIST	No. CK4400	SHEET 1 OF 3
		Rev. A	
Seal Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

SEAL DATA

Question	Y	N	R	Comments
Do drawings specify the following data?				
Seal manufacturer?				
Seal type?				
Seal size?				
Seal material?				
Seal clearance (interference) with shaft?				
Shaft diameter, surface roughness, and tolerances for sealing surface?				
Housing diameter, surface roughness, and tolerances for fit with seal?				

ASSEMBLY

Question	Y	N	R	Comments
Has gearbox assembly been reviewed to assess risk of damage to seal components?				
Are there procedures for seal assembly?				
Are clearances (interferences) with shaft per seal manufacturers recommendations?				
Are boundary dimensions per seal manufacturers recommendations?				
Are fixtures for assembly available?				

Company Name	CHECKLIST	No. CK4400	SHEET 2 OF 3
		Rev. A	
Seal Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

SEAL DESIGN

Question	Y	N	R	Comments
Are external V-rings used to protect oil seals from contamination?				
Are labyrinth seals specified (preferred)?				
Do labyrinth seals have proper clearances?				
Do labyrinth seals have at least two grooves?				
Are labyrinth seals above oil level?				
Are lip seals single lip?				
Are lip seals Viton?				
Are lip seal materials compatible with lubricant?				
Are lip seals capable of accommodating shaft endplay?				
Are lip seals capable of accommodating shaft heat?				
Do lip seals have adequate lubrication?				
Are lip seals replaceable in-situ?				
Is there adequate access for replacing lip seals?				

AGMA/AWEA 921-A97 CONFORMANCE

Question	Y	N	R	Comments
Do seals conform to AGMA/AWEA 921:				
Adequate life?				
Seal type?				

Company Name	CHECKLIST	No. CK4400	SHEET 3 of 3
		Rev. A	
Seal Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

AGMA/AWEA 921-A97 CONFORMANCE (continued)

Question	Y	N	R	Comments
Seal arrangement?				
Seal shaft/housing fits?				
Seal retainers?				
Seal clearance (interferences)?				
Seal assembly?				
Methods of lubrication?				
Seal replacement?				

Company Name	CHECKLIST	No. CK4500	SHEET 1 OF 4
		Rev. A	
Lubrication System Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

LUBRICATION SYSTEM DATA

Question	Y	N	R	Comments
Do drawings specify the following data?				
Lube system bill of materials?				
Lube system schematic?				
Lube system spare parts list?				
Lube system maintenance manual?				
Lubricant type?				
Lubricant viscosity?				
Lubricant quantity?				
Oil change interval?				

LUBRICATION SYSTEM DESIGN

Question	Y	N	R	Comments
Is oil quantity adequate?				
Are all bearings except those that dip in oil pressure-fed?				
Does oil pump have adequate capacity?				
Is oil lift (head) reasonable?				
Is filter rating $\beta_{10} \geq 200$?				
Is filter element spin-on?				
Is filter bypass ≥ 3.5 bar?				
Is pressure relief valve ≥ 3.5 bar?				
Is filter accessible for replacement?				
Is breather desiccant type?				
Does breather have 3 μm dirt filter?				

Company Name	CHECKLIST	No. CK4500	SHEET 2 OF 4
		Rev. A	
Lubrication System Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

LUBRICATION SYSTEM DESIGN *(continued)*

Question	Y	N	R	Comments
Is breather accessible for replacement?				
Is breather located in dry, nonpressurized area?				
Is breather located to direct contamination away from gears and bearings?				
Are all plumbing connections welded or reliable (no pipe threads)?				
Does oil cooler have adequate capacity?				
Does cooler have a thermostat?				
Can oil cooler be drained during oil changes?				
Does heater have adequate capacity?				
Does heater have a thermostat?				

HOUSING DESIGN

Question	Y	N	R	Comments
Does gear housing have the following features?				
Interior surfaces painted?				
Interior surfaces smooth without stagnant areas?				
Floor sloped toward drain?				
Drain at lowest point?				
Drain large size ball valve?				
Spray jets removable from outside?				
Spray jets tack-welded?				

Company Name	CHECKLIST	No. CK4500	SHEET 3 OF 4
		Rev. A	
Lubrication System Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

HOUSING DESIGN (continued)

Question	Y	N	R	Comments
Adequate inspection ports w/ handles & rubber gasket?				
Adequate dipstick?				

CONDITION MONITORING

Question	Y	N	R	Comments
Is lubrication system designed for monitoring?				
Sample port properly designed?				
Magnets provided for monitoring wear debris?				
Pressure gages on both sides of filter?				
Pop-up indicator on filter bypass?				
Low pressure switch ≤ 0.5 bar?				
Pressure differential switch on filter?				
Temperature gage at both sides of cooler?				
Thermocouple in sump?				
Thermocouple on bearings?				

AGMA/AWEA 921-A97 CONFORMANCE

Question	Y	N	R	Comments
Does lubrication system conform to AGMA/AWEA 921:				
Oil type?				
Oil viscosity?				
Oil micropitting resistance?				
Oil quantity?				

Company Name	CHECKLIST	No. CK4500	SHEET 4 OF 4
		Rev. A	
Lubrication System Design Audit		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

AGMA/AWEA 921-A97 CONFORMANCE (continued)

Question	Y	N	R	Comments
Pressure fed gears?				
Pressure fed bearings?				
Filter rating?				
Filter bypass?				
Sump temperature?				
Orifices?				
Drain and fill plugs?				
Pressurized ports?				
Oil level indicator?				
Magnetic plug?				
Oil quantity?				
Oil cleanliness?				
Breather?				

5.13 CK5000 Quality assessment

Company Name	CHECKLIST	No. CK5000	SHEET 1 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

MANAGEMENT RESPONSIBILITY

Question	Y	N	R	Comments
Is there a documented quality plan?				
Is the quality plan understood, implemented, and maintained in all departments?				
Has a person been assigned to ensure the quality plan is implemented and maintained?				
Does management periodically review the quality plan?				
Are management reviews documented?				
Is there an organizational chart that defines responsibilities of each department?				

QUALITY SYSTEM

Question	Y	N	R	Comments
Is there written procedures for the following:				
Preparing quality plans for customer requirements.				
Process control.				
Special processes.				
Receiving Inspection.				
In-process Inspection.				
Final Inspection.				
Calibration.				
Nonconforming Product.				
Corrective Action.				
Product Handling.				

Company Name	CHECKLIST	No. CK5000	SHEET 2 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

QUALITY SYSTEM (continued)

Question	Y	N	R	Comments
Product Storage.				
Product Shipping.				
Internal Quality Audits.				

CONTRACT REVIEW

Question	Y	N	R	Comments
Are there written procedures for defining contract requirements?				
Are there written procedures for ensuring capabilities meet customer requirements?				
Are all persons responsible for contract reviews identified?				
Are contract reviews documented?				

DESIGN CONTROL

Question	Y	N	R	Comments
Are responsibilities identified for each design and development activity?				
Are design requirements identified, documented, and reviewed?				
Are design calculations and analyses documented?				
Are design calculations and analyses updated as the design evolves?				
Do persons independent from the designers review design plans?				
Are design reviews documented?				
Are there procedures for distributing design documents?				

Company Name	CHECKLIST	No. CK5000	SHEET 3 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

DESIGN CONTROL (continued)

Question	Y	N	R	Comments
Are there procedures for revising design documents?				
Are codes and standards controlled for revision status?				
Is software controlled for revision status?				

DOCUMENT CONTROL

Question	Y	N	R	Comments
Is there a master list or procedure to ensure no outdated documents are used?				
Are applicable documents available at all locations where they are needed?				
Are obsolete documents removed from all points of use?				
Are all documents subject to revision control and are all revisions properly approved?				
Is there a procedure for revising:				
Routers.				
Work Orders.				
Material Specifications.				
Calibration Procedures.				
NDT Procedures.				
Purchase Orders.				
Drawings.				

PURCHASING

Question	Y	N	R	Comments
Is there an approved subcontractor list?				

Company Name	CHECKLIST	No. CK5000	SHEET 4 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

PURCHASING (continued)

Question	Y	N	R	Comments
Are subcontractors audited for capabilities to meet quality requirements?				
Are purchase orders reviewed and approved before release?				
Do purchase orders afford your customer right-of-access to audit subcontractor?				

PRODUCT IDENTIFICATION AND TRACEABILITY

Question	Y	N	R	Comments
Is product identified throughout all stages of production, delivery, and installation?				
Is product traceable to material heat and melt numbers?				

PROCESS CONTROL

Question	Y	N	R	Comments
Are documented work instructions available at each workstation?				
Do documented work instructions ensure compliance with the quality plan?				
Are workmanship criteria defined in work instructions?				
Are manufacturing and assembly procedures monitored?				
Where NDT is not possible, is the process monitored to ensure requirements are met?				

Company Name	CHECKLIST	No. CK5000	SHEET 5 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

PROCESS CONTROL (Nondestructive Testing)				
Question	Y	N	R	Comments
Are NDT technicians certified and are certifications documented?				
Is NDT equipment properly calibrated?				
Are documented NDT procedures at each NDT workstation?				
Are results of NDT properly documented?				
Is nonconforming product properly identified and isolated?				

PROCESS CONTROL (Heat Treatment)				
Question	Y	N	R	Comments
Is heat treatment equipment properly calibrated?				
Is product traceable to furnace charts and temperature records?				
Are documented heat treat procedures at each heat treat workstation?				
Are results of heat treat properly documented?				

INSPECTION AND TESTING				
Question	Y	N	R	Comments
Is received material inspected and verified to be conforming before processing?				
Are documented inspection procedures at each receiving workstation?				
Are results of receiving inspection properly documented?				
Are material test reports reviewed for conformance to acceptance criteria?				

Company Name	CHECKLIST	No. CK5000	SHEET 6 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

INSPECTION AND TESTING (continued)

Question	Y	N	R	Comments
Are documented inspection procedures at each in-process workstation?				
Are products held until in-process inspection is complete?				
Are documented final inspection procedures at each final inspection workstation?				
Are results of final inspection properly documented?				
Is nonconforming product properly identified and isolated?				

INSPECTION, MEASURING AND TESTING EQUIPMENT

Question	Y	N	R	Comments
Are measuring and test equipment calibrated to recognized standards?				
Has precision and accuracy of all measuring equipment been determined?				
Are calibration records labeled on each instrument?				
Are measuring and test equipment periodically checked for effectiveness?				
Are measuring and test equipment protected against unauthorized adjustments?				

INSPECTION AND TEST STATUS

Question	Y	N	R	Comments
Can inspection and test status of product be readily determined?				
Is product stamped or marked by other means to identify it as conforming or				

nonconforming?				

Company Name	CHECKLIST	No. CK5000	SHEET 7 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

INSPECTION AND TEST STATUS

Question	Y	N	R	Comments
Is the authority for release of conforming product documented?				

CONTROL OF NONCONFORMING PRODUCT

Question	Y	N	R	Comments
Are there areas to isolate nonconforming product?				
Is the authority for review of conforming product documented?				
Is disposition of nonconforming product documented?				
Is acceptance or rework documented to reflect actual condition?				
Is reworked product re-inspected in accordance with documented procedures?				

CORRECTIVE ACTIONS

Question	Y	N	R	Comments
Are causes of nonconforming product investigated?				
Are procedures, QA records, service reports, and customer complaints analyzed?				
Are corrective actions documented?				
Are corrective actions verified for effectiveness?				

HANDLING, STORAGE, PACKAGING AND DELIVERY

Question	Y	N	R	Comments
Are there documented procedures for:				
Handling.				

Company Name	CHECKLIST	No. CK5000	SHEET 8 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

HANDLING, STORAGE, PACKAGING AND DELIVERY (continued)

Question	Y	N	R	Comments
Storage.				
Packaging.				
Delivery.				
Is condition of stored materials assessed at intervals?				

QUALITY RECORDS

Question	Y	N	R	Comments
Are QA records controlled for:				
Identification.				
Collecting.				
Filing.				
Storage.				
Maintenance.				
Disposition.				
Retention time.				
Do quality records include:				
Management review records.				
Contract review records.				
Design review records.				
Subcontractor performance records.				
Product traceability records.				
Special process qualification records.				
Inspection and testing records.				
Calibration records.				

Company Name	CHECKLIST	No. CK5000	SHEET 9 OF 9
		Rev. A	
Quality Assessment		BY: *Author*	*DATE (date written)*
		CKD *Checker*	*DATE (date checked)*

QUALITY RECORDS (continued)

Question	Y	N	R	Comments
Nonconforming product disposition records.				
Customer complaint records.				

Appendix E

5.14 CK6000 Quality assurance plan

5.15 CK7000 Manufacturing schedule

5.16 CK8000 Manufacturing audit

Company Name	CHECKLIST	No. CK8100	SHEET 1 OF 2
		Rev. A	
Gear Raw Material		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

Question	Y	N	R	Comments
Are material certifications properly executed?				
Are forgings, bars, and coupons traceable to original heats?				
Does material conform to following minimum requirements:?				
Process- electric furnace, vacuum-degassed?				
Form- forgings with 3:1 minimum reduction?				
Form- wrought bars with 7:1 minimum reduction?				
Chemistry- conform to alloy specification?				
Chemistry- sulfur $\leq$ 0.025%?				
Chemistry- phosphorus $\leq$ 0.025%?				
Chemistry- aluminum $\leq$ 0.035%?				
Chemistry- hydrogen $\leq$ 25 ppm?				
Chemistry- oxygen $\leq$ 2 ppm?				
Grain size- 5 or finer?				
Hardenability- adequate to obtain required core hardness?				
Hardenability- Jominy data provided?				
Cleanliness- certified per AMS 2301 or ASTM A 534?				
Cleanliness- does certification show inclusion rating?				
Cleanliness- does inclusion rating meet AMS 2301 or ASTM A 534 requirements?				

Company Name	CHECKLIST	No. CK8100	SHEET 2 OF 2
		Rev. A	
Gear Raw Material		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

Question	Y	N	R	Comments
Ultrasonic inspection- are ultrasonic certifications properly executed?				
Ultrasonic inspection- are forgings inspected per ASTM A 388?				
Ultrasonic inspection- do forgings meet ANSI/AGMA 2101-C95, grade 2 acceptance criteria?				
Has material been provided for representative test coupons conforming to QP8301?				

Company Name	CHECKLIST	No. CK8300	SHEET 1 OF 2
		Rev. A	
Heat Treatment of Carburized Gears		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

Question	Y	N	R	Comments
Does heat treater have an in-house metallurgical laboratory?				
Does heat treater have a staff metallurgist?				
Does heat treater have a technician to prepare and analyze heat treat coupons?				
Does the laboratory conduct tests to ensure that the gears conform to specifications?				
Does the laboratory prepare reports that document the metallurgical test results?				
Are thermocouples properly maintained and checked against a calibration standard that is traceable to the National Bureau of Standards?				
Do thermocouples accurately measure the temperature of the gears?				
Is the carbon potential accurately maintained and monitored?				
Is the case carbon content tested with coupons?				
Are gears loaded in the furnace in a way that prevents sagging at the carburizing temperature?				
Are gears spaced so that teeth do not touch each other, baskets, or fixtures?				
Are fans used to vigorously circulate gas?				
Is there a uniform flow of gas in and around gears?				
Are quench tanks large enough for the gears?				

Company Name	CHECKLIST	No. CK8300	SHEET 2 OF 2
		Rev. A	
Heat Treatment of Carburized Gears		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

Question	Y	N	R	Comments
Is quenchant circulated with pumps?				
Is a minimum flow of 1 (one) gpm/lb of steel provided?				
Has quench vigor been determined by measuring H value?				
Is there a uniform flow of quenchant in and around gears?				
Do representative test coupons conform to the following:				
QP8301 Procedure for preparing representative test coupons				
QP8302 Inspection of surface hardness				
QP8303 Inspection of case depth				
QP8304 Inspection of core hardness				
QP8305 Inspection of case microstructure				
QP8306 Inspection for carbides				
QP8307 Inspection for decarburization				
QP8308 Inspection for carbon content				
QP8309 Inspection for microcracks				
QP8310 Inspection for secondary transformation products				
QP8311 Inspection for intergranular oxidation				
QP8312 Inspection for retained austenite				
QP8313 Inspection of core microstructure				
QP8314 Procedure for post carburizing cold treatment				

Company Name	CHECKLIST	No. CK8600	SHEET 1 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

FACILITIES

Question	Y	N	R	Comments
Is assembly area separate and clean?				
Is floor painted and clean?				
Is overhead structure clean?				
Is lighting adequate?				
Is area free of drafts?				
Is area free of tow motors?				
Are windows and doors shut?				

TECHNICIAN TRAINING and TOOLS

Question	Y	N	R	Comments
Is smoking prohibited?				
Are technicians properly trained?				
Are technicians properly equipped?				
Have technicians emptied their pockets?				
Are tools adequate and proper for job?				
Are tools in good condition and properly calibrated?				
Are tools put away immediately after use?				
Are unnecessary tools removed?				
Are metal hammers removed?				
Are machining and deburring done outside assembly area?				

Company Name	CHECKLIST	No. CK8600	SHEET 2 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

TECHNICIAN TRAINING and TOOLS (continued)

Question	Y	N	R	Comments
Are deburring tools, files, sandpaper, grinders, etc. removed from assembly area?				
Are assembly benches adequate?				
Is hydraulic press adequate?				
Is proper lifting equipment available?				
Are proper lifting techniques used?				
Are proper jacks for leveling the housing used?				

COMPONENT STORAGE

Question	Y	N	R	Comments
Are components marked with proper serial number?				
Do components have QA certificates showing conforming product?				
Are components properly stored?				
Are components covered?				
Are bearings stored on their sides?				
Are lip seals stored separately in boxes to protect them?				

COMPONENT DEBURRING

Question	Y	N	R	Comments
Are all components deburred in an area separate from assembly?				

Company Name	CHECKLIST	No. CK8600	SHEET 3 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

COMPONENT DEBURRING (continued)

Question	Y	N	R	Comments
Are gear housings deburred in separate area?				
Do all gear teeth have adequate tip, edge, and end rounds?				
Do all shaft journals have adequate chamfers?				
Do all bearing caps have adequate puller holes?				
Do all threaded holes have adequate chamfers?				

COMPONENT CLEANING

Question	Y	N	R	Comments
Are all components cleaned in area separate from assembly?				
Are gear housings cleaned in separate area?				
Are solvent tanks adequate?				
Is cleaning fluid proper?				
Are rags lint free?				
Are all drilled holes clean?				
Are all threaded holes clean?				

HOUSEKEEPING

Question	Y	N	R	Comments
Has assembly area been vacuumed before assembly starts?				
Are gear housings vacuumed before assembly?				

Company Name	CHECKLIST	No. CK8600	SHEET 4 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

HOUSEKEEPING (continued)

Question	Y	N	R	Comments
Are housing splitlines clean and flat?				
Are housing recesses and bolt holes clean?				
Are gear housings covered when unattended?				
Are all components clean and rust free?				
Are all components covered when unattended?				
Are all shaft seal surfaces covered and protected from damage?				

ASSEMBLY TECHNIQUE

Question	Y	N	R	Comments
Are shaft and gear bore diameters recorded before assembling shrink-fit gears?				
Are shaft diameters recorded before assembling bearing inner races?				
Are bearing inner races heated with an induction heater?				
Are bearing inner races held against shaft shoulder during cooling?				
Is pushing through rolling elements disallowed?				
Is hammering disallowed on any bearing components?				

Company Name	CHECKLIST	No. CK8600	SHEET 5 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

ASSEMBLY TECHNIQUE (continued)

Question	Y	N	R	Comments
Are separable C-R bearings assembled with adequate tools and procedures to avoid damage?				
Do bearings rotate freely after assembly with shaft?				
Are bearing endplays properly set?				
Are bearing pins properly installed?				
Are bolts properly torqued?				
Are lockwires properly applied?				
Are all seals pressed into retainers without hammers?				
Are all lip seals lubricated at assembly?				
Are all seals assembled over shafts using sleeves to protect seal lips?				
Are all shafts free to float axially with housing cover installed?				
Is housing free of M_oS_2?				

CONTACT PATTERNS

Question	Y	N	R	Comments
Are contact patterns checked in housing per CK8700?				
Are splitlines leveled using leveling jacks?				
Are splitlines flat?				

Company Name	CHECKLIST	No. CK8600	SHEET 6 OF 6
		Rev. A	
Gearbox Assembly		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

CONTACT PATTERNS (continued)

Question	Y	N	R	Comments
Is marking compound clean and properly applied?				
Are covers installed before contact pattern testing?				
Are dowel pins installed?				
Are gears rolled with light torque?				
Is cover removed for inspection?				
Are patterns documented with tapes?				
Is marking compound removed?				
Is DYKEM tested for compatibility with lubricant?				
Is DYKEM properly applied?				
Are covers installed using sealant sparingly?				

PREPARATION FOR TESTING

Question	Y	N	R	Comments
Are all gear housing openings sealed?				
Do all gearsets have adequate backlash?				
Do lube system components conform to lube schematic?				
Are guidelines for tests being followed?				

Company Name	CHECKLIST	No. CK8800	SHEET 1 OF 5
		Rev. A	
Gearbox Test		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

TEST PLAN

Question	Y	N	R	Comments
Is there a written test plan?				
Does test plan specify proper loads, speeds, & runtimes?				
Does test plan specify sound test per ANSI/AGMA 6025?				
Does test plan specify vibration test per ANSI/AGMA 6000?				
Does test plan specify records of bearing temperatures?				
Does test plan specify records of oil temperatures?				
Does test plan specify records of contact patterns?				

HOUSEKEEPING

Question	Y	N	R	Comments
Are all gearbox and lube system ports closed?				
Are oil drum ports closed?				
Are oil drum tops clean?				
Take oil samples from drums?				
Is oil transfer pump flushed with clean oil?				
Is area around gearbox clean?				
Is gearbox free of debris, tools, rags, and unnecessary hardware?				
Are gearbox breathers installed?				

Company Name	CHECKLIST	No. CK8800	SHEET 2 OF 5
		Rev. A	
Gearbox Test		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

HOUSEKEEPING (continued)

Question	Y	N	R	Comments
When opening ports are the following precautions followed:				
Open ports one at a time?				
Clean inspection cover & area around port before opening?				
Count inspection cover bolts before opening?				
Keep inspection cover bolts in separate containers?				
Technicians have nothing in shirt pockets?				
Flashlights & tools on lanyards?				
Ports closed immediately after inspection?				
All inspection cover bolts accounted for?				

LUBE SYSTEM CHECKOUT

Question	Y	N	R	Comments
Lube system components per Bill of Material?				
Lube system plumbed per lubrication schematic?				
Lube system connections properly bolted?				
Lube system electrical connections properly made?				
Oil type correct?				

Company Name	CHECKLIST	No. CK8800	SHEET 3 OF 5
		Rev. A	
Gearbox Test		BY: *Author*	DATE *(date written)*
		CKD: *Checker*	DATE *(date checked)*

LUBE SYSTEM CHECKOUT (continued)

Question	Y	N	R	Comments
Oil level correct?				
Oil filter correct?				
Oil filter 3-way valve set so filters are operational?				
Magnetic trap 3-way valve set so trap is operational?				
Is magnetic trap clean?				

LUBE SYSTEM TEST

Question	Y	N	R	Comments
Jog pump motor. Rotation correct?				
Run lube system w/o rotating gearbox and check following:				
Pump motor quiet?				
Oil pump quiet?				
Leaks in piping, housing, or oil seals?				
System oil pressures per specification?				
Filter differential pressure per specification?				
Oil level correct?				
Open inspection ports (see housekeeping). Oil flow correct?				

Company Name	CHECKLIST	No. CK8800	SHEET 4 OF 5
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Gearbox Test		BY: *Author*	DATE *(date written)*
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GEARBOX SPIN TEST

Question	Y	N	R	Comments
Jog drive motors. Rotation correct?				
Run lube for 15 min before rotating gearbox?				
Shutdown and check magnetic trap. Magnetic trap clean?				
Start gearbox rotation and set speed to specification?				
Record lube pressures, filter differential pressure, and oil temperatures every 15 min.?				
Run (2 hours minimum) until oil temperatures stabilize?				
Leaks in piping, housing, or oil seals?				
Record sound per ANSI/AGMA 6025?				
Record vibration per ANSI/AGMA 6000?				
Internal accelerometers operational?				
Check oil pressure switch set points?				
Check oil temperature switch set points?				
Take oil sample from petcock?				

Company Name	CHECKLIST	No. CK8800	SHEET 5 OF 5
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Gearbox Test		BY: *Author*	DATE *(date written)*
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POST TEST INSPECTION

Question	Y	N	R	Comments
Shutdown and check magnetic trap. Magnetic trap clean?				
Open inspection ports (see housekeeping). Internals clean and free of distress?				
Open inspection ports (see housekeeping). Contact patterns per procurement specification?				
Record contact patterns?				
Close all inspection ports and prepare for shipping?				

TEST REPORT

Question	Y	N	R	Comments
Does test report record the following:				
Inspectors name?				
Date?				
Gearbox serial number?				
Loads, speeds, & runtimes?				
Oil type?				
Sound per ANSI/AGMA 6025?				
Vibration per ANSI/AGMA 6000?				
Bearing temperatures?				
Oil temperatures?				
Contact patterns per procurement specification?				
Certification that test data conform to requirements of procurement specification?				

Company Name	CHECKLIST	No. CK9101	SHEET 1 OF 14
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APPLICATION DATA

Question	Y	N	R	Comments
Customer?				
Site?				
Type of application?				
Audit conducted by?				
Date of audit?				
Other?				

DOCUMENTATION

Question	Y	N	R	Comments
Documents available?				
Installation drawing?				
Assembly drawing of gearbox?				
Lubrication schematic?				
Lube system bill of material?				
Maintenance manual?				
Service history?				
Oil lab analyses?				
Oil change interval records?				
Filter change interval records?				
Alignment records?				
Vibration records?				
Sound records?				
Temperature records?				
Other documents?				

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DRIVER NAMEPLATE DATA

Question	Y	N	R	Comments
Driver type?				
Driver serial number?				
Power?				
Speed?				
Service factor?				
Other?				

DRIVER NAMEPLATE DATA

Question	Y	N	R	Comments
Driven type?				
Driven serial number?				
Power?				
Speed?				
Service factor?				
Other?				

GEARBOX NAMEPLATE DATA

Question	Y	N	R	Comments
Gearbox type?				
Gearbox manufacturer?				
Gearbox model?				
Gearbox serial number?				
Power?				
HS shaft speed?				
LS shaft speed?				
Service factor?				
Gear ratio?				

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Gear System Audit		BY: *Author*	DATE *(date written)*
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GEARBOX NAMEPLATE DATA (continued)

Question	Y	N	R	Comments
Lubricant specification?				
Lubricant viscosity?				
Lubricant volume?				
Temperature limits?				
Other?				

OPERATIONAL DATA

Question	Y	N	R	Comments
Continuous duty?				
Intermittent duty?				
Runtime/day?				
Total runtime logged?				
Other?				

ENVIRONMENT AUDIT

Question	Y	N	R	Comments
Record ambient temperature?				
Record relative humidity?				
Water evident?				
Corrosion evident?				
Contamination evident?				
Overheating evident?				
Adequate airflow?				
Typical start-up temperature?				
Typical running temperature?				
Other?				

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FOUNDATION AUDIT

Question	Y	N	R	Comments
Baseplate solid?				
Mounting bolts tight?				
Driver shimmed properly?				
Gearbox shimmed properly?				
Driven shimmed properly?				
Other?				

ALIGHNMENT AUDIT

Question	Y	N	R	Comments
Couplings per installation drawing?				
HS coupling type?				
LS coupling type?				
Date of last alignment?				
HS coupling alignment data?				
LS coupling alignment data?				
Coupling lubricant per spec?				
Date lube last changed?				
Other?				

LUBRICATION SYSTEM AUDIT

Question	Y	N	R	Comments
Lube system components per Bill of Material?				
Lube system plumbed per lubrication schematic?				
Lube system connections properly bolted?				

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LUBRICATION SYSTEM AUDIT (continued.)

Question	Y	N	R	Comments
Lube system electrical connections properly made?				
All openings properly sealed?				
Oil vendor correct?				
Oil type correct?				
Oil viscosity correct?				
Oil capacity correct?				
Oil level correct?				
Oil filter correct?				
Valves set so oil filter is operational?				
Oil filter clean?				
Heat exchanger correct?				
Heater correct?				
Valves set so magnetic trap is operational?				
Is magnetic trap clean?				
Breather correct?				
Breather clean?				
Dwell time ≥ 4 minutes?				
Suction ≥ 150 mm below surface?				
Return below surface?				
Suction and return separate?				

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HOUSEKEEPING

Question	Y	N	R	Comments
Are all gearbox and lube system ports closed?				
Are oil drums properly stored?				
Are oil drum ports closed?				
Are oil drum tops clean?				
Take oil samples from drums?				
Oil transfer pump flushed with clean oil?				
Is oil transferred thru a filter?				
Is area around gearbox clean?				
Is gearbox free of debris, tools, rags, and hardware?				
Gearbox breathers installed?				
When opening ports are the following precautions followed:				
Open ports one at a time?				
Clean inspection cover & area around port before opening?				
Count inspection cover bolts before opening?				
Keep inspection cover bolts in separate containers?				
Technicians have nothing in shirt pockets?				
Flashlights & tools on lanyards?				
Ports closed immediately after inspection?				
All inspection cover bolts accounted for?				

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GEARBOX INSPECTION

Question	Y	N	R	Comments
Inspect exterior for following:				
Overheating?				
Corrosion?				
Contamination?				
HS shaft oil leaks?				
LS shaft oil leaks?				
Breather leaks?				
Other leaks?				
Housing damage?				
Inspect interior for following:				
Overheating?				
Corrosion?				
Contamination?				
Sludge?				
Varnish?				
Wear debris?				
Take samples of oil?				
Take samples of wear debris?				
Record bearing endplay?				
Record backlash?				
Record contact patterns?				
Photograph gear teeth?				
Failure modes (AGMA 1010):				
Cold flow?				

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GEARBOX INSPECTION (continued)

Question	Y	N	R	Comments
Hot flow?				
Indentation?				
Rolling?				
Rippling?				
Ridging?				
Root fillet yielding?				
Tip/root interference?				
Root fillet cracks?				
Profile cracks?				
Tooth end cracks?				
Nonprogressive macropitting?				
Progressive macropitting?				
Spall macropitting?				
Flake macropitting?				
Micropitting?				
Subcase fatigue?				
Adhesion?				
Abrasion?				
Corrosion?				
Fretting corrosion?				
Polishing?				
Electric discharge?				
Cavitation?				
Erosion?				
Scuffing?				

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GEARBOX INSPECTION (continued)

Question	Y	N	R	Comments
Hardening cracks?				
Grinding cracks?				
Rim and web cracks?				
Case/core separation?				

LUBE SYSTEM TEST

Question	Y	N	R	Comments
Jog pump motor. Rotation correct?				
Run lube system w/o rotating gearbox and check following:				
Pump motor quiet?				
Oil pump quiet?				
Piping vibrating?				
Leaks in piping, housing, or oil seals?				
System oil pressures per specification?				
Filter differential pressure per specification?				
System oil temperatures per specification?				
Oil level correct?				
Oil pressure switch set points correct?				
Oil temperature switch set points correct?				
Take oil samples?				

Company Name	CHECKLIST	No. CK9101	SHEET 11 OF 14
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Gear System Audit		BY: *Author*	DATE *(date written)*
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GEARBOX TEST

Question	Y	N	R	Comments
Jog drive motors. Rotation correct?				
Run lube for 15 min before rotating gearbox?				
Open inspection ports (see housekeeping). Oil flow correct?				
Shutdown and check magnetic trap. Magnetic trap clean?				
Start gearbox rotation and set speed to specification?				
Record lube pressures, filter differential pressure, and oil temperatures every 15 min.?				
Run (2 hours minimum) until oil temperatures stabilize?				
Leaks in piping, housing, or oil seals?				
Record sound per ANSI/AGMA 6025?				
Record vibration per ANSI/AGMA 6000?				
Record bearing temperatures?				
Record oil temperatures?				

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Gear System Audit		BY: *Author*	DATE *(date written)*
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POST TEST INSPECTION

Question	Y	N	R	Comments
Shutdown and check magnetic trap. Magnetic trap clean?				
Shutdown and check oil filter. Oil filter clean?				
Open gearbox inspection ports (see housekeeping):				
Internals clean and free of distress?				
Contact patterns correct?				
Record contact patterns?				
Misalignment evident?				
Wear steps evident?				
Oil foam evident?				
Open lube system inspection ports (see housekeeping):				
Oil foam evident?				
Overheating?				
Corrosion?				
Contamination?				
Sludge?				
Varnish?				
Wear debris?				
Take samples of oil?				
Take samples of wear debris?				
Close all inspection ports and return system to operation?				

Company Name	CHECKLIST	No. CK9101	SHEET 13 OF 14
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Gear System Audit		BY: *Author*	DATE *(date written)*
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AUDIT REPORT

Question	Y	N	R	Comments
Inspectors name?				
Date?				
Gearbox serial number?				
Calculate pitchline velocity?				
Oil type per ANSI/AGMA 9005?				
Oil viscosity per ANSI/AGMA 9005?				
Oil per gearbox nameplate?				
Oil pour point at least 5°C below start-up temperature?				
Sound per ANSI/AGMA 6025?				
Vibration per ANSI/AGMA 6000?				
Record bearing temperatures?				
Record oil temperatures?				
Record contact patterns?				

Company Name	CHECKLIST	No. CK9305	SHEET 1 OF 4
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Gearbox Bearing Removal and Inspection		BY: *Author*	DATE *(date written)*
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DISASSY PLAN/PREPARATION

Question	Y	N	R	Comments
Is there an assembly drawing?				
Review assembly drawing with technician?				
Are all necessary tools available?				
Does technician understand need to proceed at pace that is slow enough to gather data?				
Is notebook ready for documenting procedure & recording observations?				
Is camera ready for documenting procedure & recording observations?				

HOUSEKEEPING

Question	Y	N	R	Comments
Is disassy area clean and uncluttered?				
Take oil samples from gearbox?				
Is area around gearbox clean?				
Is gearbox free of debris, tools, rags, and unnecessary hardware?				
Are gearbox breathers installed?				
When opening ports are the following precautions followed:				
Open ports one at a time?				
Clean inspection cover & area around port before opening?				
Count inspection cover bolts before opening?				

Company Name	CHECKLIST	No. CK9305	SHEET 2 OF 4
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Gearbox Bearing Removal and Inspection		BY: *Author*	DATE *(date written)*
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HOUSEKEEPING (continued)

Question	Y	N	R	Comments
Keep inspection cover bolts in separate containers?				
Technicians have nothing in shirt pockets?				
Flashlights & tools on lanyards?				
Ports closed immediately after inspection?				
All inspection cover bolts accounted for?				

GEARBOX DISASSY

Question	Y	N	R	Comments
Match mark bearing retainer cap & housing?				
Photograph bearing retainer cap?				
Remove bearing retainer bolts following housekeeping rules?				
Photograph interior of bearing retainer cap?				
Photograph visible parts of bearing?				
Photograph wear debris?				
Collect wear debris?				
Match mark bearing outer race and housing?				
Match mark bearing inner race and shaft?				
Complete disassy of gear housing?				

Company Name	CHECKLIST	No. CK9305	SHEET 3 OF 4
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Gearbox Bearing Removal and Inspection		BY: *Author*	DATE *(date written)*
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GEAR/BEARING REMOVAL

Question	Y	N	R	Comments
Photograph bearing in housing?				
Remove gears from housing being careful not to damage bearing?				
Photograph bearing on shaft?				
Check with feeler gauge to ensure bearing is against shaft shoulder?				
Remove bearing from shaft without pulling through outer race (use split puller)?				

PREPARATION FOR SHIPMENT

Question	Y	N	R	Comments
Do not clean bearing. Prepare for shipping in bearing's own oil?				
Wrap bearing in rust preventative paper?				
Wrap bearing in leak-proof plastic?				
Pack in sturdy carton?				
Ship by UPS to GEARTECH?				

COMPONENT INSPECTION

Question	Y	N	R	Comments
Inspect shaft diameter. Is diameter to drawing spec?				
Inspect bore diameter. Is diameter to drawing spec?				
Inspect shaft fillet radius. Is radius to drawing spec?				

Does new bearing have proper part number?				

Company Name	CHECKLIST	No. CK9305	SHEET 4 OF 4
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Gearbox Bearing Removal and Inspection		BY: *Author*	DATE *(date written)*
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COMPONENT INSPECTION (continued)

Question	Y	N	R	Comments
Does new bearing have proper internal clearance?				
Are shaft diameter, housing bore, & interfaces free of burrs?				

BEARING/GEARBOX ASSEMBLY

Question	Y	N	R	Comments
Heat bearing with hot oil or induction heater?				
Install on shaft and clamp against shaft shoulder while cooling?				
Check with feeler gauge to ensure bearing is against shaft shoulder after bearing is cool?				
Install gear/shaft assembly in gear housing without lifting through bearing?				
Install housing top cover?				
Install bearing retainer cap?				
Check bearing endplay?				
Spin test gearbox (see GEARTECH CK8800)?				

6 NREL Checklist

Certification auditors must have a clear guideline for the minimum information that should be included in the design documentation of a gearbox. The basic requirements are set by standards but the certification body must translate those requirements into specific technical information. It is important for the designer to know what the auditor will be looking for so that he/she can make sure it is contained in the design documentation/specifications. The following form is a distillation of the checklists presented in section 7 and is seen as assuring the minimum requirements set in the IEC standards are met. It is intended for auditors and designers.

6.1 DF16 Gearbox Evaluation